THE PRESERVATION

OF

TIMBER

BY THE USE OF

ANTISEPTICS.

BY

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PREFACE.

The preservation of wooden structures from decay, or from the ravages of insects, is a subject of unfailing interest to engineers.

The fact that this paper was prepared for the Institution of Civil Engineers, and was discussed by prominent members, is a sufficient guaranty that it presents the facts that are best worth knowing now in the possession of practical men.

Some chemical tables, appended essays, and a long bibliographical list are omitted in this reprint.

THE

ANTISEPTIC TREATMENT OF TIMBER.

IN January, 1853, a paper upon Timber Preserving was contributed to this Institution* by the author's partner, the late Mr. Henry Potter Burt, Assoc. Inst. C. E. Since that date, the use of Antiseptics for the treatment of timber has largely increased, and is year by year increasing. For engineering purposes, the process called creosoting, which consists in the injection of the coal-tar oils, has in this kingdom entirely, and in other countries to a very considerable extent, displaced the other well-known methods.

Concurrently with this development, a series of remarkable discoveries in chemical science has raised the manufactures connected with the residual prod-

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ucts of gas-making to a position of great and growing importance.

It is proposed in the present paper, to give a short account of the history and development of the use of antiseptics for preventing the decay of timber. A reference to the processes employed in coal-tar distillation will be pertinent to the subject, in so far as it will indicate what are and have been the usual constituents of the tar oils used for injecting wood. The author proposes to add some results derived from his thirty-four years' experience in connection with this group of manufactures, together with the outcome of some research, and of a number of experiments specially undertaken with a view to the elucidation of questions referred to in the paper.

EARLY HISTORY OF TIMBER PRESERVING.

Timber was naturally the first material employed by man for the purposes of constructive engineering. If it be true that the first models of Grecian architecture were copied from, and re-

tained some of the distinctive features of, buildings in wood, then may still be seen recorded, upon the columns of the five great orders of architecture, proofs that the Greeks or their precursors took special expedients to preserve timber from decay. The wooden pillar was placed upon a block of stone to preserve it from the humidity of the soil, and it was covered at the top by a slab or tile to throw off the rain. These contrivances are supposed to have been copied in the base and capital of the column, when wood came to be replaced by stone. Scamozzi imagines also, that the mouldings represent metal hoops, placed around the wooden pillars to prevent them from splitting.

Allusions to various substances employed for preserving timber and other vegetable fibers from decay, are frequent in the writings of the ancients. Tar and pitch were used for painting or smearing wood from periods of the most remote antiquity. Greek and Roman authors narrate, that the astringent portions of

the oil expressed from olives (Amurca 16), also oils derived from the Cedar, the Larch, the Juniper and the Nard-Bush (Valeriana) were used for the preservation of articles of value from decay, or from the attacks of insects. The magnificent statue of Zeus by Phidias was erected in a grove at Olympus where the atmosphere was damp; the wooden platform upon which it stood was therefore imbued with oil. The famous statue of Diana at Ephesus was of wood. If its origin was believed to be miraculous, no standing miracle was relied on for its preservation. Pliny asserts upon the authority of an eye-witness, Mucianus, that it was kept saturated with oil of Nard by means of a number of small orifices bored in the woodwork. The same author remarks that wood well rubbed with oil of Cedar, is proof aginst wood-worm and decay. The art of extracting and preparing oils, resins, tar and pitch from various trees and plants, and from mineral deposits, is mentioned by Herodotus, and at great length by

Pliny. This last author describes in detail, the manufacture of no less than forty-eight different kinds of oils. Of the employment of the oxides or salts of metals by the ancients, for wood preserving, there is no direct evidence.

EGYPTIAN MUMMIES.

Of all the methods employed by mankind for the artificial preservation of organized substances, there are perhaps none which have equaled in success the processes of the ancient Egyptians. The durable results of these processes are amazing, and although the topic is a hackneyed one, it is nevertheless inseparably connected with the subject of this paper. The descriptions by co-temporary writers of the Egyptian art of embalming the dead are somewhat conflicting; moreover, they do not adequately explain the appearances presented by many of the mummies themselves. The bodies are said to have been imbued, either with resinous or odoriferous gums, or more frequently with bitumen or with oil

of cedar, or commonly with natrum, and often with several of these substances in succession. So far, these statements are confirmed by modern investigation. By reading Herodotus and Diodorus Siculus, however, it would perhaps seem that the body was first steeped in the natrum for seventy days, and then subjected to the oily or bituminous preparation. In other places it might be gathered that the oily preparation came first, and the steeping in natrum afterwards. Without further explanation, neither of these processes would appear to be practicable. At ordinary temperatures, the steeping in the one preparation would interfere with the absorption of the other. Natrum is supposed to have been a natural substance, obtained from some briny lakes, still existing in the neighborhood of Cairo, and consisting principally of a mixture of sodium-sesqui-carbonate, sodium-chloride and sodium-sulphate. Rouyer, who accompanied the army of Napoleon to Egypt in 1798, expressed his

conviction that the mummies had been placed in ovens in order to eliminate moisture, and to facilitate the penetration of the bitumen. But no ancient author mentions any such process, nor is there any record of it amongst the numerous and detailed pictorial representations which have been discovered in tombs and temples.

Pettigrew, in his valuable work on this subject, whilst giving the results of his examination of various mummies, and of analyses of embalming materials, expresses his opinion that the bodies must have been subjected to a very considerable degree of heat, as even the inmost structure of the bones is penetrated by the antiseptics. By some it has been supposed that this was effected by steeping the body in a cauldron of heated bitumen. Pettigrew's most striking experiment was made with the heart of a mummy, from which he succeeded in withdrawing by maceration the preservative substances, when, after 3,000 years of perfect preservation, the heart began at

once to putrefy. This is a striking proof, both of the efficacy of the substances employed, and also of the fact, that the immunity from decay was not due to a chemical transformation produced once for all, but that it depended upon the abiding presence of the antiseptic. In recent anatomical practice, carbolic acid has been used for injecting bodies for purposes of dissection. When this is done, however, it is found necessary to renew the process after the lapse of a few weeks, a contrast to the antiseptics employed by the Egyptians. Pettigrew's description showed that the worst preserved of the mummies are those prepared with natrum alone, the most perfect being those in which solid resins or bitumens remain incorporated. Natrum is frequently found accompanying the bitumen in some of the most successfully preserved specimens. It is probable that some astringent or other substances were also used, the secret of which has hitherto eluded modern investigation.

The author has caused some experi-

ments to be made with pieces of timber, in order to test a theory which suggested itself to his mind. The wood was first thoroughly impregnated with a mixed solution of the three salts of sodium of which the natrum brine is composed Afterwards the wood was steeped in tar oil, heated to 230° Fahrenheit. The heat of the tar oil volatilized the water of the soda solution, and the oil took the place of the water. The timber remained impregnated with the saline particles, and saturated with the tar oil. May not this have been the method used by the Egyptians to impregnate both with natrum and oils?

There is no doubt that the ancients had, by observation and experience, acquired considerable practical knowledge of antiseptic substances. They were also of opinion that those woods lasted the longest which were most odoriferous, or, in other words, those which contained the greatest quantity of resin. They knew that timber continually kept under water was less liable to decay than when

exposed to the atmosphere. They observed the ravages of the *Teredo navalis* upon timber placed in the sea. But it is useless to seek amongst the writings of the elder Classics for any reasonable theory in explanation of these phenomena.

Growth of theories upon the causes of Putrefaction.—It is not until the eighteenth century of the present era that anything beyond the merest trace can be detected of serious analytical research into the causes of decomposition. After the fanciful dreams of the alchemists had been dissipated, the more solid portion of their labors, facts arrived at in the course of their experiments, remained for the uses of science. Investigations were undertaken respecting the phenomena of fermentation and of putrefaction, animal and vegetable. It was at one time declared that putrefaction was due to the escape of an element called phlogiston, an imaginary substance which was believed in by such eminent chemists as Scheele, the discoverer of chlorine, and Dr. Priestley, the discoverer of

oxygen. Later on Dr. Macbride propounded a theory that carbonic acid gas had a special power of promoting cohesion, and that putrefaction was due to its being given off. None of these theories explained why putrefaction did not attack the tissues until after the vital movement had ceased. By the commencement of the present century, however, it began to be generally believed that the putrefaction, at least of vegetable matter, was a species of fermentation, although it was not admitted that ferments of any kind were the products of living organisms. Little by little the similarity of the natural processes connected with the fermentation of alimentary substances, the decay of vegetable tissues, and the putrefaction of the bodies of animals began to be recognized; and, to the great advantage of scientific progress, these three classes of phenomena have ever since been studied in close connection with each other.

In the meantime practice stole a march upon theory. About the year 1770 Sir

John Pringle published a list of antiseptics, in which example he was followed by Dr. Macbride. Many of the substances proposed by these and other theorists, particularly the alkaline bodies, are absolutely injurious to timber. But towards the close of the last century and at the beginning of the present, experiment was greatly stimulated by the wants of the British navy. During the colossal struggles of Great Britain with hosts of adversaries, the very existence of the nation appeared to be staked upon her fleets. The great prevalence of dry-rot in the timbers of British men-of-war assumed the proportions of a national calamity. It was said that a single 70-gun ship required for its construction the oak of 40 acres of forest, and that the supply would fail. It was in 1812 that Lukin tried, in the Woolwich Dockyard, his disastrous experiment with the injection of resinous vapors. More practical suggestions were soon forthcoming, and the use of the salts of various metals began to be recommend-

ed. Sir Humphrey Davy suggested corrosive sublimate; Thomas Wade (in 1815), the salts of copper, iron, and zinc. The opinion gained ground that poisons of various kinds were correctives to the decay of timber.

From the year 1768 up to the present time, the records of the Patent Office contain lists of almost every conceivable antiseptic, suitable or unsuitable, for the preservation of wood.

Progress during the Railway Era.—But it is since the birth and growth of the railway system that the antiseptic treatment of timber may be said to have received its most important development. The stone blocks and other solid supports, at first used for the permanent way of railways, were found to be too rigid, and had to be replaced by a more elastic material. The wooden sleepers which were substituted decayed so rapidly that some artificial method for prolonging their duration began to be considered as an engineering necessity. By the year 1838, four several systems of antiseptic

treatment were fairly before the public, and competing for the favor of engineers. These were: Corrosive sublimate, introduced by Mr. J. H. Kyan; sulphate of copper, by Mr. J. J. Lloyd Margary; chloride of zinc, by Sir William Burnett; heavy oil of tar (afterwards called creosote), by Mr. John Bethell.

Corrosive Sublimate, or bichloride of mercury, was successfully used by Homberg, a French savant, in 1705, for preserving wood from insects. It was recommended by De Boissieu in 1767. In 1730 the Dutch Government tried it upon wood immersed in sea water as a remedy against the *Teredo navalis*, but for this purpose it failed. In the "Encyclopædia Britannica," in 1824, it is recorded that Sir Humphrey Davy recommends its use for timber. Kyan's first patent, for the employment of corrosive sublimate for wood-preserving was taken out in 1832. His first success was gained by the preservation of the woodwork of the Duke of Devonshire's conservatories. Kyanizing was for a long time by far the

most popular of the timber-preserving processes in this country, and the name is to this day frequently applied erroneously to other systems. Used in sea-water, however, by the British Admiralty, this process turned out a failure, as it had done under similar circumstances with the Dutch government a century earlier. Kyanizing has met with a considerable amount of success in comparatively dry situations; but in water, and particularly in sea-water, it appears to have invariably failed, as have all the salts of metals. Corrosive sublimate is somewhat volatile at ordinary temperatures; it also has the drawback of producing injurious effects upon the workmen employed in handling it.

Sulphate of copper.—The use of this and of other salts of copper was recommended by De Boissieu and by Bordenave in 1767, and by Thomas Wade in 1815. In 1837 Mr. Margary took out a patent for the use of sulphate and ascetate of copper. Sulphate of copper has perhaps been the most successful of all

the metallic salts as an antiseptic for timber. Applied in various ways it was popular in France long after it had been given up in this country. It is still in use in France, to a limited extent, for sleepers and telegraph poles.

Chloride of zinc.—This was recommended by Thomas Wade in 1815, and by Dr. Boucherie in 1837; and a patent for its application was taken out in this country by Sir William Burnett in 1838. The process of Burnettizing was at one time much patronized by the British Admiralty. For railway sleepers it was extensively adopted in France by the author's firm, principally on the railways from Orleans to Bordeaux, and from Caen to Cherbourg. It is no longer used in France, but it is still employed in Holland and in Germany. Chloride of zinc is a powerful antiseptic, but its weak point for wood-preserving consists in its extreme solubility in water.

Heavy oils of Tar, commonly called Creosote.—As early as 1756 attempts were made, both in England and Ameri-

ca, as described by Knowles, to inject or impregnate timber with vegetable tars or with extracts therefrom. The first mention of the products of the distillation of gas-tar, to be used separately for impregnating timber, appears to be by Franz Moll. This inventor took out a patent in 1836 for injecting wood in closed iron vessels with the oils of coal-tar first in a state of vapor, and next with the heated oils in the ordinary liquid state. He recommended the adoption both of the oils lighter than water, and of the oils heavier than water, calling the former "Eupion," and the latter "Kreosot." He relied upon the Kreosot for its antiseptic qualities, but proposed to use the light oils separately, at the commencement of the operation, for the purpose of facilitating the absorption of the heavy oil. This plan has never been acted upon, as it would be obviously wasteful and unpractical to inject the lighter oils, or crude naphthas, which would immediately evaporate.

The practical introduction of the proc-

ess is due to Mr. John Bethell. His now celebrated patent, which is dated July, 1838, does not mention the words "Creosote" or "Creosoting." It contains a list of no less than eighteen various substances, mixtures or solutions, oleaginous, bituminous, and of metallic salts. Amongst them is mentioned a mixture consisting of coal-tar thinned with from one-third to one-half of its quantity of dead oil distilled from coal-tar. This is the origin of the so-called Creosoting process. Creosote, correctly so called, is the product of the destructive distillation of wood, and coal-tar does not contain any of the true Creosote, which has never been used for timber-preserving. But a substance, since called carbolic acid, or phenol, had been discovered in coal-tar; it was thought by some to be identical with the Creosote of wood, hence the process came to be miscalled, after a time the creosoting process. It is in this popular sense only that the word Creosote is to be understood in the remainder of this paper. The two sub-

stances, Creosote and Carbolic acid, are described and contrasted, and their varying properties delineated in Dr. Tidy's "Handbook of Chemistry."

Competition of the Processes—Theory of Eremacausis.—In addition to the four processes already mentioned, a patent for a fifth was taken out by Mr. Charles Payne in 1846. His plan consisted in the injection into the timber, first of a solution of a sulphuret of barium or calcium, and next of a solution of sulphate of iron, the object being to form an insoluble sulphuret in the pores of the wood. This process was tried to some extent both in England and in France, but it was a complete failure, and is mentioned only by way of reference.

From 1838 to 1853, at which last date the paper of Mr. H. P. Burt was read at this institution, the four processes, Kyanizing, Margaryizing, Burnettizing and Creosoting had been in active competition. The prevailing theory at that time as to the causes of the decay of timber was shaped by the opinions of the great

chemist Liebig. Liebig taught that the processes of fermentation in certain fluids and of the putrefaction or decay of organized bodies, animal and vegetable, were caused by a species of slow combustion, to which he applied the term eremacausis. He held that this decomposition could be produced by contact with portions of other bodies already undergoing eremacausis. That it required for its ordinary development the presence of moisture and of atmospheric air; that its action was provoked by oxygen, and that its method of action was by a communication of motion from the atoms of the infecting ferment to the atoms of the body infected. He denied that fermentation, putrefaction and decomposition were caused by fungi, animalcules, parasites or infusoria, although these organisms might sometimes be present during the processes.

But he also stated that the phenomena of decomposition might be suspended by extreme heat or cold, that they were accelerated by the action of alkalies, and

retarded by that of acids, and that they might be arrested by the use of certain antiseptics. If, however, the theory of eremacausis be accepted, and if its phenomena be due entirely to a communication of molecular motion, and not at all to the action of living germs, does any adequate explanation remain of the effects produced by antiseptics? With regard to timber, theorists were ready with an answer to this question, and they deduced their theories from further teachings of the great German chemist. Liebig, enlarging upon the views of previous investigators, had proclaimed the identity in composition of the animal and vegetable albumens. The blood of animals and the sap of plants are, during life, the circulating media of the vital growth; after death they are the portions of the respective bodies which putrefy most rapidly; both are largely composed of albumen. The sap freshly drawn from a tree will commence to putrefy within twenty-four hours. It was proclaimed (although probably not by

Liebig), that the coagulation of the albumen was the true specific against the decay of wood. Corrosive sublimate, sulphate of copper, chloride of zinc, and the tar oils were all powerful agents for that purpose. It was claimed for all four of these processes that they coagulated the albumen contained in the wood, and that they formed insoluble compounds therein, thus arresting decay.

Prolonged experience has, however, proved that the salts of metals are not so permanent in their effects as the tar oils. The discussion which took place at this institution in January, 1853, upon the occasion of the reading of Mr. Burt's paper, was an interesting one, and was joined in by most of the leading engineers of the country. Whilst the other processes were admitted, in many instances, to have done good service, the Creosoting process was generally held, after fifteen years' experience, to have proved the most stable and reliable. In many subsequent discussions, the prolonged duration of creosoted timber had

been a matter of constant and reiterated testimony. Gradually the Creosoting process took the place of the others by a species of "survival of the fittest," until in England it entirely extinguished its rivals. The author's last experience of Kyanizing in England was carried out in 1863.

In France, the Creosoting process was later in establishing itself, partly owing to the difficulty which at one time existed in procuring Creosote in that country, partly, also, to the popularity of the sulphate of copper process, enhanced, as it was by the ingenuity of the method employed for its injection by Dr. Boucherie. But it was discovered even in France, and notwithstanding the theories of insoluble compounds being formed in the timber, that the salts of metals were gradually washed out of the wood in moist situations. In 1861, the French chemist Payen reported that sulphate of copper could be almost entirely removed from wood by repeated washings with water, and in 1867 he reported that the

whole could be so removed. This has been confirmed by the testimony of Maxime Paulet.

The experiments of Mr. Forestier, undertaken for the French Government, and the prolonged and exhaustive experiments of the Dutch Government, are conclusive as regards the efficiency of creosoting against the ravages of the *Teredo navalis*, in cases where the timber has been efficiently prepared, and with a suitable kind of creosote. These experiments are referred to in the Minutes of Proceedings of this Institution, vol. xxvii. The experiments undertaken by Mr. Crepin on behalf of the Belgian Government, and the independent testimony of many of the leading engineers of this country, have also from time to time been brought to the notice of this Institution, in confirmation of the success of the Creosoting process against the ravages of marine insects. On the other hand, there are distinct and well authenticated instances of failure. An inquiry

into the causes of such failures is one of the main objects of this paper.

Origin and properties of the Tar Oils.—As the tar oils gained in usefulness, their varying qualities became subjects of increasing interest. A brief digression may here be useful, in order to show the process of manufacture by which these tar oils are procured. It will be seen that from coal, as it is carbonized at the gasworks, four well-known products are obtained, viz., illuminating gas, ammoniacal liquor, coal-tar, and coke. Gas liquor, or ammoniacal liquor forms the basis of a separate industry; the ammoniacal products are of no utility for timber preserving. The antiseptic substances are all obtained from the distillation of coal tar, a black, viscous substance of a consistency resembling treacle. The tar is subjected to the heat of a furnace placed beneath the still, the operation being aided sometimes by the injection of steam, sometimes by the application of an exhausting air pump. The products of distillation come over very nearly

in the order of their respective volatilities, those of lightest specific gravity being followed in succession by heavier and yet heavier ones as the heat increases. The temperature during the distillation ranges from 180° to 758° Fahrenheit. This preliminary process, although now carried out with more skill and economy than formerly, has not varied much during the last fifty years in its main object, which is to break up the tar into three groups of products, viz., oils lighter than water (crude naphthas); oils heavier than water, pitch, the residuum of distillation, which last product is run out from the bottom of the still, and solidifies, upon cooling, into a hard, black substance. It is in connection with the component parts of the two groups of oils, and their separate and subsequent treatment, that some of the best known and most brilliant discoveries of modern industrial chemistry have been developed. The oils lighter than water, however, have no part in the preservation of timber. It is not uncommon to hear inquiries as to

whether the discovery of the aniline dyes has not, somehow or other, interfered with the quality of the Creosoting liquor. There exists a singular and unfounded prejudice on this subject. The materials for the aniline dyes are not, and never have been, taken from the Creosoting liquor or heavy oils; they are taken exclusively from the oils lighter than water, which last have never been employed for the Creosoting process, and are valueless for timber-preserving. The benzols, toluols, &c., from which the aniline dyes are produced, are extremely volatile, like alcohol.

The heavy oils of tar, or dead oils heavier than water, constitute the "Creosote" of the timber yards. They contain numerous substances, some of them liquid, some semi-solid, varying considerably in their properties, but most of them are now recognized as antiseptics. Formerly, the whole mass of these heavy oils was used for timber-preserving as they were collected from the still, but each portion can, if required, be separ-

ated as it comes over, according to its volatility, or the solid matters can be separated by filtering, for subsequent treatment.

It has been seen that Mr. Bethell's original patent recommended the use of the mother liquor, or coal tar, thinned with a portion of heavy coal-tar oil. So late as 1849, Bethell's licenses for the use of his patent described the process as "saturating timber with the oils obtained by the distillation of gas-tar, either alone or mixed with gas-tar." The author remembers how, in the early days of Creosoting, inspectors frequently refused to allow the thinner and lighter dead oils to be used without being thickened with tar. Tar, the mother liquor, necessarily included all the substances contained in the dead oils, plus the naphthas and the pitch. The reasons for not adopting the tar in its entirety are simply that the crude naphthas are useless as antiseptics, and would immediately evaporate, whilst the pitch, from its too great solidity, would form an impediment to

the injection. The dead oils, therefore, came into use alone, and there crept into some of the specifications the contradictory prescriptions that the wood was to be Creosoted according to Bethell's patent, but that the Creosote was to be free from adulteration with coal tar.

The dead oils made in London, and in all places where the tar is produced from the carbonization of the coal of the Newcastle district, are, as compared with other dead oils, the richest in semi-solid substances (naphthalene, anthracene, pyrene, &c.), and they require a higher temperature to volatilize. They are generally called "London oils." The dead oils of the Midland Districts are lighter, thinner, and more volatile, and contain usually a larger proportion of the ordinary tar acids. They are usually called "Country oils." The Scotch oils are, many of them, still lighter, thinner, and more volatile, sometimes lighter than water. Some Scotch oils, however, have been proved to be of excellent quality.

As regards the question of thick or

thin oils, there is no doubt as to the opinion and practice of the earlier introducers of the Creosoting process. In January, 1853, Mr. Bethell stated that "the product of Newcastle coal contained a quantity of naphthalene, and that he was an advocate for its use." In November, 1864, he said that "the Creosoting process was not, as often described, a chemical process entirely"; that Creosote did coagulate albumen in the sap of the wood; "but that was not his only idea when he introduced the process: his object was to fill the pores of the wood with a bituminous asphaltic substance, which rendered it waterproof," &c.

The late Mr. H. P. Burt, whose labors in connection with the preservation of timber will be remembered by many of the elder members of the engineering profession, was in the habit, for many years, of using, by preference, the heavy London oils, mixed at times with a small percentage of the country oils, the latter as solvents or diluents of the more solid

material. The author, whose connection with Mr. Burt commenced in 1850, remembers, among his first experiences of creosoting, the solid masses of naphthalene contained in the tanks before heating.

When the construction of railways commenced in India in 1850 and 1851, it was speedily discovered that the timber found in that country was subject to very rapid destruction by decay and by the attacks of insects. A serious difficulty was encountered by engineers in procuring suitable sleepers, and the experiment was tried of sending creosoted Baltic timber from this country. The first consignment of this material was sent out in December, 1851, for the East Indian Railway Company. The results were promising from the first, and the exportation of creosoted sleepers to India continually increased. The Minutes of Proceedings of this Institution contain numerous records of the rapid decay of unprepared timber in tropical climates, and also of the very

great general success of creosoted timber exposed to the same influences, checkered, however, with a few instances of partial failure, which should be as instructive as the successes. It may be interesting to refer to the two papers by Mr. Bryce McMaster, upon Indian Permanent Way materials, one read in 1859, and the second in 1863, in which the success of creosoted timber in India is fully set forth. Mr. Juland Danvers, in his annual report to the Secretary of State for India for the year 1863, remarks that it is cheaper to send out creosoted Baltic sleepers than to use those of indigenous wood. The printed report of the East Indian Railway Company for the year 1867 again records the success of creosoted sleepers, after sixteen years' experience of their use.

It becomes a matter of interest to ascertain the kind of Creosote which was used for these earlier Indian sleepers. When the exportation first began there was a custom's duty upon the importation of Baltic timber into this country

equal to about 20 per cent. on the value of the sleepers. The author's firm made early arrangements for creosoting in bond, and for this reason, and with trifling exceptions, all the sleepers sent abroad, although supplied by various contractors, were for many years creosoted at the works of the author's firm at Rotherhithe and at the Victoria docks. Their books contain accurate records of the origin of all the creosote used. As may be anticipated, by far the greater bulk was London oil, up to 1863 comparatively little country oil, and in some years none at all being used. In January, 1853, Mr. Burt, in describing to this Institution the process which he used, spoke, as a matter of course, of Creosote becoming a hard, compact mass at a temperature below 35° Fahrenheit. Ten years later, in February, 1863, speaking with reference to the Creosoting of some sleepers, the success of which in India had just been announced, he described Creosote as becoming solid at a temperature below 40° Fahrenheit, and added

that, in consequence, he had introduced a heating apparatus inside the Creosoting cylinder.

With the exception of a small experimental shipment of larch and Scotch fir, all the sleepers sent to India have been of Baltic fir timber from the Polish and Russian ports. The shipments were of the ordinary kind of wood, such as was in use at first for sleepers in this country, and were mostly of triangular section. Amongst them, for the first three or four years, were considerable quantities of white-wood, a wood somewhat liable to split in hot countries. Subsequently, red-wood was stipulated for, and with good reason, in all Indian specifications. The quantity of Creosote injected into these sleepers was at first from 35 to 40 gallons to the load of 50 cubic feet, as compared with the 50 and 60 gallons of the present day. At present not only is a larger quantity of Creosote injected, but more care is also expended in the selection of the wood than was formerly the case. If, therefore, the earlier sleepers

shipped to India behaved well, it might be assumed that the quality of the Creosote, at least, was suited to the climate. Such Creosote, however, as was then used would now be rejected under the requirements of many of the specifications at present in force for the preparation of timber for tropical countries. It is a question for grave consideration whether the change has been for the better.

It is a matter of notoriety, that for many years an increasing demand has arisen for the thinner and lighter Creosotes. "Country oil" became more popular, and began to be mentioned in specifications. Inspectors preferred these thinner oils; they were injected with less trouble, and the timber looked cleaner and less "muddy" after the process, especially in the winter, when the London oils are more solid. Contrary to the opinion of the introducers of Creosoting, the thin, light "Country oil" came to be considered by many as the supreme type of excellence.

This view was adopted by the late Dr. Letheby, who was further influenced by the growing recognition of the wonderful antiseptic powers of carbolic acid. Discovered in coal tar by Runge, a German chemist, in 1834, carbolic acid had gradually achieved the important position which it still holds as one of the most valuable of antiseptics for sanitary and surgical puposes. Carbolic acid in varying quantities was present in the tar oils; the other constituents of those oils were imperfectly understood; some of them, now well known, had not then been discovered. The success of the creosoting process was therefore by *a priori* reasoning attributed mainly, if not solely, by Dr. Letheby to the presence of the tar acids. In June, 1860, Dr. Letheby published his views on this subject in the "Journal of the Society of Arts." He considered carbolic acid to be the most effective constituent of the tar oils, and that the efficiency of the latter in preserving timber depended mainly upon the percentage of carbolic acid which

they contained. He therefore concluded that the lighter portions of the dead oils were the best, viz., those portions distilling between 360° Fahrenheit and 490° Fahrenheit, as they contain the tar acids in greatest abundance. Naphthalene and para-naphthalene he desired to exclude as much as possible, as he held them to be of no value in the preparation of timber. He had found the proportion of carbolic acid in tar oils to range from 6 per cent. down to as low as 0.5 per cent. In a letter of his in the author's possession, dated 5th June, 1863, he alludes to two samples as containing "unusually large" proportions of tar acids; the quantities were respectively 6.4 per cent. and 10.1 per cent. In a lecture at Nottingham, in 1867, Dr. Letheby described a specification which he had drawn up for an Indian railway. This specification, dated 1865, contains the following stipulations: The creosote is to have a specific gravity as near to 1,050 as possible, ranging from 1,045 to 1,055. It is not to deposit naphthalene or para-naph-

thalene at a temperature of 40° Fahrenheit. It is to contain 5 per cent. of crude carbolic and other coal-tar acids (by the caustic potash test). It is to yield 90 per cent. of liquid oil, when distilled from its boiling point to a temperature of 600° Fahrenheit.

From an examination of upwards of seventy timber-preserving specifications in the author's possession, ranging from 1849 to the present year, it is manifest that a new departure was thus inaugurated by Dr. Letheby. For the first time a boiling-point is fixed, a certain percentage of tar acids insisted upon, whilst the use of naphthalene and the heavier distillates is discouraged. This specification has long ceased to be used, but its stipulations have been copied, and in some cases carried to greater lengths, in more modern specifications, 10 per cent. of tar acids being occasionally required. Such specifications exclude the London oils if taken in their entirety as they come from the still. It is to be regretted that, at the period mentioned, there

is no record of experiments having been made by any English chemists as to the actual effects produced upon timber by the various constituents of the tar oils taken separately. For want of such a test, it would appear that an important element in the question was for some years overlooked in this country.

So early as 1848 the French Académie des Sciences received a communication from De Gemini, detailing a series of experiments upon wood prepared with various antiseptics. This investigator endeavored to prove that timber cannot be permanently preserved by the use of antiseptics which are themselves soluble in water, and for that reason he preferred the use of heavy oils, or bituminous substances. The Académie rejected the conclusions of De Gemini, more especially as he denied that solutions of sulphate of copper formed insoluble compounds with woody fiber.

In 1862 Mr. Rottier presented a paper to the Académie Royale de Belgique giving the results of a number of experi-

ments as to the effects upon timber of the various constituents of coal-tar oil. He arrived at the conclusion that although carbolic acid (L'Acide Phénique) was a very energetic antiseptic, yet that, owing to its volatility, the durable success of the Creosoting process was not due to its agency. He attributed that success to the heavier and less volatile portions which came over at the later periods of the distillation, and considered that the heavier they were the better.

Later on this investigation was taken up by Mr. Charles Coisne, who was then, and still is, an engineer in the service of the Belgian Government. In 1863 Mr. Coisne commenced a series of experiments, the object being to determine, in a practical manner, which portions of the tar oils best preserved the timber. The results were so instructive, that in 1866 he inaugurated a new series of experiments, still more carefully conducted, which lasted until 1870. He procured samples of Creosote from England, Scot-

land, Belgium and France. Four of these samples contained, respectively, 15 per cent., 15 per cent., 8 per cent., and 7 per cent. of tar acids by the usual test. The fifth was an oil of heavy specific gravity, specially prepared, and containing no tar acids. Yet this last sample produced better results than any of the others. Each sample was divided into portions. Wood shavings were saturated with these oils in the following different ways:

1st. With the Creosotes as received.

2d. With the Creosotes, supplemented by additional quantities of tar acids.

3d. With the Creosotes, supplemented by some of the heavier portions of the same oils distilling over at a temperature exceeding 320° Centigrade (628° Fahrenheit).

4th. With the original Creosotes divided into the lightest, the medium, and the heaviest portions, with each of which the shavings were separately saturated.

A putrefying pit (*pourrisoir*) was pre-

pared, in which the shavings were placed on the 10th of November, 1866, together with other shavings not prepared. After four years' sojourn in the *pourrisoir*, they were removed and examined on the 16th November, 1870. The results were strikingly in favor of the heavier oils, and adverse to the tar acids, which last bodies appeared to have been wholly ineffective. The shavings which had been prepared with the lightest portions of the oils, although they had contained the largest portions of the tar acids, were, nevertheless, in the worst condition. Those prepared with the oils somewhat heavier were in most cases better preserved. Best of all were the shavings prepared with the heaviest oils, procured by distilling at the higher temperatures even when containing no tar acids; these last were all perfectly sound. The un-creosoted shavings were all rotten. Mr. Coisne believed that the best portions of the oils were the "green oils," distilling at high temperatures.

These experiments are recorded at

length in the "Annals des Travaux Publiques de Belgique," also in separate pamphlets. Their results have considerably influenced the practice of railway engineers on the Continent. The Belgian Government accepted the conclusions arrived at by Mr. Coisne, and for many years has based its creosoting specifications thereon, with highly satisfactory results. The specification for the Belgian State Railways does not stipulate for any tar acids; it requires that at least two-thirds of the Creosote must have been obtained by distillation at a temperature exceeding 250° Centigrade (482° Fahrenheit), and the remainder at a temperature exceeding 200° Centigrade (392° Fahrenheit). It allows 30 per cent. of naphthalene, which is calculated at the ordinary temperature. In a recent correspondence with the author, Mr. Coisne, who has for more than twenty years superintended the Creosoting operations of the Belgian Government, confirms the results of those experiments by his subsequent experience.

So far, the experiments and the experience of De Gemini, Rottier and Coisne appear to be in absolute contradiction with the theory that the Creosoting process owes its success to the tar acids. Yet the fact cannot be doubted, that the tar acids are powerful antiseptics, and that their presence arrests decay. What, then, is the explanation of this apparent anomaly?

The authorities on the tar acids are many and reliable. From amongst the learned and voluminous treatises which have been written respecting these bodies, fifteen references have been made to authors in England, Scotland, France, Belgium, Germany and America. None of them disagree as to the following facts: That carbolic acid is volatile at ordinary temperatures. That it is soluble in water. That its combinations are not stable. That it is a powerful germicide, but that its efficacy ceases so soon as it evaporates or is washed out of the substances intended to be preserved. Professor (now Sir Joseph) Lister, whose adoption of

the antiseptic system for surgical purposes has revolutionized hospital practice, speaks from his large and valuable experience as to the importance of carbolic acid in the treatment of wounds, but he also remarks that its volatility is sometimes an evil as well as a good. Dr. Sansom, whose recent work on antiseptics so ably epitomizes the results arrived at by previous investigators, as well as those due to his own researches, speaks of it as the "aerial disinfectant" *par excellence.*

If this substance can be washed out by water, and if its volatility is one of its great merits, and occasionally a defect, for sanitary purposes, can it at the same time be considered as a durable agent amongst the oils injected into railway sleepers? Especially can this be the case in those tropical countries where extreme heat or torrential rains, or alternations of both, are prevalent? For piles and other timbers used for harbor-work, the comparative solubility in water of the antiseptic agents employed is

also a matter of vital importance. What is true respecting carbolic acid, will also apply, to a great extent, to cresylic acid, the last substance being, however, somewhat less volatile and less soluble than the former. Do these bodies become stable by entering into combination with woody fiber? Their instability in this connection is apparently pointed out by Mr. Coisne's experiments. It may, however, be objected that these experiments were not conducted under the conditions to which railway timbers are exposed. This point also has been very fully investigated.

In 1867 Mr. Coisne obtained some Creosoted sleepers which had successfully resisted decay during periods of from eighteen to twenty years. The wood was crushed, and the substances obtained therefrom tested. He found no tar acids; if they had ever been there, they were no longer present. He found, however, a quantity of naphthalene; also of an oil which did not commence to dis-

til until 230° Centigrade (446° Fahrenheit).

In 1882 the author caused some similar experiments to be made. Through the kindness of the authorities of the London and North-Western Railway Company, eleven pieces of old Creosoted sleepers were sent from their permanent way. They had been in use for the following periods:

1 specimen	16	years.
1 "	17	"
2 "	20	"
2 "	22	"
1 "	28	"
2 "	29	"
1 "	30	"
1 "	32	"

Sleepers were also received from the Taff Vale Railway, the South-Eastern Railway, and the Great Eastern Railway, which had been in use periods varying from fourteen to twenty-three years. A portion was also taken from a Creosoted pale fence, which had been fixed in the Victoria docks in 1855, and which is still in place, perfectly sound and strong,

after twenty-nine years' use. A careful analysis of these seventeen specimens, all of ordinary Baltic fir, gave the following results:

1st. In no cases were any tar acids detected by the ordinary tests.

2d. In fourteen out of the seventeen specimens the semi-solid constituents of the tar oils were present; in twelve of them was naphthalene, this body being in some cases in considerable quantity.

3d. Only small percentages remained of oils distilling below 450° Fahrenheit. In the majority of instances from 60 per cent. to 75 per cent. of the total bulk of substances retained in the wood did not distil until after a temperature of 600° Fahrenheit was reached.

It is clear, therefore, that these timbers had been preserved by the action of the heaviest and most solid portions of the tar oils, and that the other constituents had disappeared.

4th. In some of these specimens acridine was searched for and detected. This substance is one of the alkaloids or

bases now known to exist in the Creosote oils. This is probably the first occasion upon which acridine has been publicly mentioned in connection with the injection of wood; but the author is persuaded that it will come to be recognized as one of the most valuable constituents of the tar oils for timber-preserving purposes. It was discovered by Graebe and Caro; it is a powerful germicide, and solidifies within the pores of the timber, from which it neither evaporates nor washes out. It is intensely acrid and pungent.

Portions of the same specimens of wood, fifteen in number, were sent to Mr. Greville Williams, whose original researches with relation to coal derivatives have been for so many years known to the scientific world. Mr. Greville Williams tested the samples of wood for tar acids, naphthalene, and the alkaloids. For the tar acids he found all ordinary tests fail, until he employed the extremely delicate one by bromine and ammonia. In some cases, even by this test, no

phenols could be detected, but in most cases he succeeded in detecting faint traces of those bodies; generally less than one part in three thousand; minute portions, probably of the heaviest particles of the tar acids which had been incorporated and retained by the heavier portions of the oils. It is needless to say that these infinitesimal quantities could be of no practical value in preserving the wood. In all the specimens, save two, he found naphthalene. The presence of the antiseptic alkaloids was distinctly proved, and one of these bodies, called cryptidine, which he had discovered in Creosote oils, in 1856, was detected by him in one of the specimens. Mr. Greville Williams concludes that the preservative action of the Creosote oils is due more to the bases or alkaloids than to the tar acids, as the former remain after the latter have disappeared. These researches were published in the "Journal of Gas Lighting," and also in a pamphlet in the possession of this Institution.

First, and most volatile of all the Creosote oils, are the carbolic and cresylic acids, which are also freely soluble in water at ordinary temperatures; they come over from the still, incorporated with the lightest portions of the oils. Pure carbolic acid would entirely disappear by evaporation, if not secured in a stoppered bottle. Next in order comes naphthalene, which is much less volatile than the tar acids. It is not soluble in cold water, and almost insoluble in boiling water. As it comes from the still it is of a yellowish color, and mixed with the heavy oils, it gradually becomes black on exposure to the atmosphere. It forms the principal constituent of the thick, muddy-looking substance which sometimes forms on the surface of Creosoted timber, and which may often be seen adhering to the ends of railway sleepers for several years after they have been placed in the line. When sublimed by the action of heat and a current of air, it forms the beautiful frost-like substance well known in Creosoting yards. It becomes

quite solid at a low temperature, and in that condition would be an impediment to the injection of the timber—a difficulty removed by heating the oils to about 100° Fahrenheit, at which temperature naphthalene becomes liquid. After injection it solidifies, and greatly assists in filling up the pores of the wood.

The following simple experiments, which have been tried and repeated in many different ways at the author's laboratories during the last few years, are in strict accordance with the now well-known characteristics of naphthalene and the tar acids:

1. If tar acids and naphthalene be separately exposed either at the ordinary temperature, or at the tropical heat of 130° Fahrenheit, the tar acids will evaporate with much more considerable rapidity than naphthalene.

2. Injected into timber the same results follow.

3. Light, thin oils, containing large percentages of tar acids, evaporate more quickly than heavier oils containing less

tar acids and more naphthalene, when tested by methods Nos. 1 and 2.

In weighing after these experiments great care must be taken to allow for the absorption of moisture from the atmosphere. The tar acids absorb moisture before finally evaporating. Wood also absorbs a large amount of moisture when injected with oils containing these acids.

4. By repeated washings with cold water, all the carbolic acid, and all or nearly all the cresylic acid, can be washed out, both from country and from London oils. These experiments assume especial importance in considering the durable effects of various kinds of creosote for protecting timber immersed in sea-water from the attacks of marine insects.

Dr. Meymott Tidy has published the results of his experiments upon naphthalene. He injected pieces of wood with this substance, and exposed them to a temperature of 150° Fahrenheit. He found that the evaporation was only superficial, and that it practically ceased after forty-eight hours, the naphthalene

below the surface remaining within the pores of the wood. Naphthalene is now recognized as an antiseptic, not so powerful in its immediate effects as the tar acids, but more durable. It is probable that tar acids of a heavier and less volatile type than carbolic or cresylic acids, may be more reliable as antiseptics for preserving timber.

Following in the series of distillates, amongst the Creosote oils are the alkaloids or bases of the quinoline or leucoline group, amongst which chemists are searching, not without fair promise of success, for a febrifuge similar to, if not identical with, the quinine derived from the cinchona plant. In this group occurs the substance called cryptidine, already alluded to as one of the valuable antiseptics discovered in those portions of the oils which were formerly characterized as "inert."

Para-naphthalene, mentioned in Dr. Letheby's specification, has since then become the basis of one of the most interesting chemical discoveries of the age.

It was excluded by Dr. Letheby from the oils intended for timber preserving, and is probably without value for that purpose. It is now called anthracene, and is extremely valuable as the substance from which alizarine is manufactured, thanks to the brilliant discoveries of Perkin in England, and of Graebe, Liebermann and Caro in Germany. Alizarine is the coloring matter used by Turkey-red dyers and printers; for ages it had been extracted from the madder root. It is now made from the coal-tar product anthracene, of a far higher degree of purity, and at an enormously decreased cost. The madder root has gone almost entirely out of cultivation. The quantity of anthracene contained in tar is relatively small.

Amongst the green oils, distilling between 550° Fahrenheit and 750° Fahrenheit, is found the acridine already alluded to as a valuable germicide and stable antiseptic. Phenanthrene, carbazol, pyrene, chrysene and benzerythrene, by no means complete the list, which is

constantly being added to by new discoveries of the numerous bodies in which these dead oils are so prolific. The properties of many of these heavier bodies are still imperfectly understood; but from the fact that they will not evaporate except at exceedingly high temperatures, they are valuable ingredients for timber-preserving.

By the light of the evidence now accumulated, it may be advisable to review the question as to the relative value of these various bodies contained in the heavy oils as regards the preservation of timber. Some of them are becoming valuable for other purposes. Which of them should the engineer retain for injecting wood?

Can the conclusion be resisted, that for this purpose the efficacy of the tar acids has been overrated, and this at the expense of the more stable and enduring portions of the tar oils? The London oils as they come from the still are not sufficiently volatile to meet the exigencies of some modern specifica-

tions, nor do they comply with these exigencies as regards the percentage of tar acids. They do not, as a rule, contain more than from 4 to 7 per cent. of tar acids, and they will not yield 90 per cent. of their bulk by distillation below 600° Fahrenheit. Therefore a pressure is put upon the manufacturer to meet the fashion by "taking out" some of the heavier portions, and in some instances this is done. By this means the bulk is rendered lighter, and the proportion of tar acids to the diminished bulk is increased. For these heavier portions, especially for the green oils, a market is found for lubricating and other purposes. But in the author's judgment the efficacy of the oils as antiseptics for wood is thereby diminished. The green oils, after the anthracene has been removed from them by filtration, should be returned to the Creosote tank. The percentage of tar acids to be used remains a contested matter of opinion. But the author ventures to express the hope that at least the lighter portions of the tar

acids, and especially carbolic acid, may soon be relegated altogether to their important functions as sanitary antiseptics, for which they are so valuable, instead of being wasted by the attempt to use them as antiseptics for timber, for which their peculiar properties render them unreliable. Upon the whole it would be wiser to revert, to a larger extent and with increased knowledge, to the plan of using the London oils mixed with the country oils, and encouraging instead of discouraging the use of the heavier portions. The whole of the Creosote oils manufactured from ordinary gas tar in this country are required for preserving timber, and to exclude one considerable portion of the supply is to enhance unnecessarily the cost of the rest. No oils, however, should be used as Creosotes which are lighter than water. Both bone oil and shale oil are sometimes offered as Creosote oils.

In 1881 Professor (now Sir Frederick) Abel and Dr. Tidy drew up a joint Creosoting specification, in which, as the

result of direct experiment, they resolved to exclude no semi-solid bodies which completely melt at 100° Fahrenheit. They further changed the standard of volatility from 90 per cent. at 600° Fahrenheit to 75 per cent. Subsequent and prolonged investigation induced Dr. Tidy to go still further in the same direction, and not only to withdraw the clause limiting to 25 per cent. the oils distilling at a higher point than 600° Fahrenheit, but even to require that at least 25 per cent. of those non-volatile oils must be present. The author's experience leads him entirely to agree with the progress made in this direction.

CONFLICTING THEORIES ON PUTREFACTION—THE GERM THEORY.

If experiment and experience should lead to clearer views as to the relative value of various antiseptics, it may be advisable to test those views by reference to the recent development of theory upon the causes of decomposition in organized bodies. How do antiseptics act

upon timber? Is the coagulation of albumen a sufficient explanation of their preservative action? Surely not. Many substances, boiling water included, which will effectually coagulate albumen, will not prevent the decay of wood. Coagulation retards, but does not prevent, the decay of albumen itself. Again, the quantity of albumen in fir timber is exceedingly small, if the tree be cut down, as it generally is and always should be, during the season when the sap is not circulating. From a number of experiments made upon ordinary fir sleepers, the author arrives at the conclusion, that the quantity of nitrogenous matter or albumen which they contain does not usually much exceed 1 per cent. of their weight. Any watery fluid containing from 2 to 3 per cent. of tar acids would effectually coagulate this quantity of albumen. In some cases it is found that a portion of this albumen is actually coagulated by substances naturally contained in the timber. But the coagulation does not of itself preserve the wood.

Leibig's theory of decomposition has already been alluded to. He maintained that putrefaction was due to eremacausis or slow combustion, produced by contagion, the infected bodies communicating a molecular motion to the atoms of the bodies with which they come in contact, and that these phenomena are not caused by the action of germs or living organisms.

The modern germ theory distinctly traverses this last assertion. Pasteur affirms, that without the presence of living germs, the phenomena of organic decomposition do not accomplish themselves, and that these germs are the veritable agents of the decomposition. The laborious experiments, and the lucid deductions of Professor Tyndall confirm the experiments and theories of Pasteur. Professor Tyndall explains that the air is laden with clouds of germs, agents of decomposition, ever ready to settle down and develop upon matter suitable to their growth. He finds that the contents of tubes filled with the

most putrescible materials, animal or vegetable, can be preserved from putrefaction indefinitely, by the exclusion of germs. But that it is not sufficient merely to poison or neutralize one generation of organisms, the incursions of fresh myriads must be excluded, or putrefaction will ensue.

After reading the "Essays on the Floating Matter of the Air," in which Professor Tyndall describes how the germs gradually fell into the open tops of the test-tubes, let the comparison be made between the mouths of these tubes and the gaping orifice of a crack produced by the sun in a piece of timber. Through it the germs will descend, and if there is nothing to arrest their action, and if the crack is deeper than the portion of the wood charged with antiseptics, they will carry destruction into the center of the log. But if the antiseptic be of an oily or bituminous nature, it will flow into the cracks when they first develop themselves, and seal up the orifices against the enemy. Examine a

crack or a wound in the trunk of a living fir tree; it will be found that by a natural process, a resinous substance exudes, which closes the wound against the agents of destruction.

The bodies of mammoths preserved in ice through countless ages, the trees of primeval forests excluded from the air beneath thick deposits of peat, the fragments of wooden piles which have endured undecayed for centuries when driven deeply below the surface of water, all confirm the experiments of Pasteur and Tyndall, and prove that the exclusion of germs prevents putrefaction. Specimens are exhibited of a wooden pile from the remains of the bridge (destroyed by fire) which was constructed by Charlemagne across the Rhine at Mayence; of pieces of piles from the foundations of the bridge across the Medway at Rochester, which was destroyed by Simon de Montfort in 1264, and which was probably then about one hundred years old; also from the new

bridge erected to replace the former one in 1283.

It is not for the author to draw the dividing line between the decomposing action of germs and the action of oxidation. It is sufficient for his purpose to submit that all influences which either destroy or exclude germs, will prevent decay so long as those influences endure; but that permanent effects must not be relied upon from agents which are not themselves permanent and abiding. The germ theory then becomes a severe but a salutary test in choosing antiseptics for the treatment of timber. Such treatment is of little value unless its effects will endure for long periods. Reliance, therefore, must not be placed upon those germicides, however potent, which will readily volatilize in air, or dissolve in water. A growing skepticism arises from experience as to insoluble compounds being formed between woody fiber and substances which are themselves soluble in water. In short, the substances to be employed should by

preference be antiseptics in a double sense; they should be both germicides and germ excluders. From the long list of germicides must be especially excluded such as injure or weaken the fiber of the wood; amongst these latter must be classed all solutions with very strong acid or alkaline reactions; also some of the metallic salts. It has been seen, that the salts of zinc, mercury, and copper have been to some extent successful; of these the author's experience induces him to prefer sulphate of copper, as less soluble in water than chloride of zinc, and not volatile like corrosive sublimate. Even sulphate of copper cannot be permanently relied upon, when exposed to the continuous action of water; but it may be found useful in comparatively dry situations, or as a protection against dry-rot to timber under cover. From its properties as a germicide, sulphate of copper might be usefully employed in conjunction with oily or bituminous fluids, even with oils which do not possess great potency as germicides.

From all research and experience it would, however, appear that the same conclusions may be derived, viz., that the best antiseptics for timber are to be found amongst oils and bitumens which fill up the pores of the wood. Of such bodies, those which contain germicides are to be preferred. And, other properties being equal, those which either solidify in the pores of the wood or which require an extremely high temperature to volatilize them, and which are insoluble in water, must surely be the best of all.

Apparatus for Timber-Preserving.—Of the apparatus employed for applying antiseptics to wood, the most ancient and the most popular is the tar brush or the paint brush. During the last century, and in the earlier portion of the present, steeping in tanks was extensively adopted, the various liquids being employed either cold or heated. A marked improvemen' was introduced in 1831 by Mr. Breant, ı director of the Mint of Paris, who invented the first apparatus for injectin

timber by means of vacuum and pressure, in a closed iron cylinder; he employed, by preference, linseed oil and resin. The cylinder was fixed vertically, an inconvenient arrangement not necessary to the efficiency of his process. The iron cylinder and the process by vacuum and pressure were adopted by Mr. Bethell, and greatly improved by him and by Mr. H. P. Burt, who were associated together for some years. The cylinder was enlarged, its fittings strengthened and simplified, and an interior heating apparatus added. In Mr. Burt's paper of January, 1853, there is a full description of this machinery; its main features are still the same in the usual Creosoting apparatus of the present day. These cylinders, being of wrought-iron, were applicable to Creosote oils and to chloride of zinc, but not to salts having a corrosive action upon iron, such as sulphate of copper and corrosive sublimate. In 1842, Mr. Timperley described to this Institution a method which he had adopted on the Hull and Selby Railway,

for lining the iron cylinder, in order to preserve it from the action of corrosive sublimate. This method and the expedient of smearing the inner surface with pitch were proposed and tried for sulphate of copper injections with but partial success. The author had several cylinders materially injured or destroyed by the corrosive action of these salts. In 1857 Messrs. Lege and Fleury Peronnet introduced an apparatus of which the cylinder, trucks and pressure pumps were entirely of copper, and machinery of this costly description is still used for the Compagnie des Chemins de Fer du Midi, at Labouheyre. In 1865 the author took out a patent for the following apparatus: Inside the iron cylinder he placed a wooden tank, which contained the timber to be operated upon, and in which was the sulphate of copper solution. It was an open wooden tank, inside a closed iron cylinder. The pressure applied was that of condensed air, a condensing air-pump being used, capable of maintaining an effective pressure of 200 lbs. to

the square inch. By this means the timber was injected with the copper solution without injury to the iron cylinder.

The process of Dr. Boucherie was at one time largely used in France. It consisted in the injection of newly-fallen timber in the forest by the vertical pressure of a column of the antiseptic solution, generally sulphate of copper, which was conducted through a pipe from a small reservoir fixed at a height of 30 or 40 feet. The tube was attached by an ingenious arrangement to the end or middle of the log; the antiseptic liquid expelled the sap from the softer parts of the timber, and took its place. The process is still used to a small extent in France, principally for telegraph poles.

Various attempts have been made to imbue timber with the vapors of oils, either by employing the tensions of the vapors themselves, or by the use of the pressure-pump. The first experiment of this kind appears to have been made by Lukin, in the dockyard at Woolwich in 1812, when the apparatus exploded, with

fatal consequences to the workmen employed, and the attempt was abandoned. The patents of Franz Moll in 1836, of Bethell in 1864, and other subsequent patents, claim the invention of the principle of injecting Creosote oils in a state of vapor. If this could be conveniently or safely carried out, the system might possess some advantages. But there is a fatal objection to its employment. Timber is weakened by exposure to a temperature much exceeding 250°Fahrenheit, whilst at 300° Fahrenheit, or a little above, it commences to decompose, and becomes seriously injured. Now the boiling point of the Creosote oils ranges from a little below 400° Fahrenheit up to 760° Fahrenheit. As with the steam of water, so is it with the vapor of oils—no pressure can be obtained with them, except at a temperature exceeding their boiling point. The vapors of the Creosote oils cannot, therefore, be injected into timber except at temperatures, and under conditions of pressure, which would destroy the value of the timber as

an engineering material. The process has been tried in France, and it failed, owing to the complete deterioration of the timber.

A modification of this system has, however, been carried into practice. Super-heated steam was passed through Creosote oils, and then injected into the sleepers (which had been previously warmed by steam) with the idea that the mingled vapors of water and Creosote might be injected into the timber at a temperature of from 290° Fahrenheit to 320° Fahrenheit. With this modified process, the author's firm carried out some extensive operations for the Compagnie des Chemins de Fer de l'Ouest, it being the desire of the engineers of that company to economize the Creosote, and to try whether in a finely divided state, a smaller quantity might not suffice by being more deeply injected. The operation was supplemented, however, by an injection of Creosote in the usual fluid state.

After prolonged trials, the first part

of the operation was discontinued by order of Mr. Bouissou, the company's engineer of the permanent way. It was found, whenever the cylinder was opened before the second operation, that a small portion of the lightest particles of the Creosote had been carried over mechanically into the cylinder by the superheated steam. Once within the cylinder, however, the two fluids obeyed the laws which govern their respective volatilities: the Creosote oil sank to the bottom of the cylinder, and the vapor of water only was injected into the timber. The sleepers on examination and testing by the ordinary tests, contained neither tar oils nor tar acids.

An analogous experiment tried at the Timber Preserving Works of the Austrian North-West Railway, is described in the journal of the Architects and Engineers' Institute of the Kingdom of Bohemia for 1880, by Herr J. Seidl, and the process has been condemned for very similar reasons.

Condition of Timber at Time of

Preparation.—Getting Rid of Moisture by Stacking or Artificially.—The hygrometric condition of timber at the time of injection is an important element in the success of the operation, all important with the Creosoting process especially. Neglect on this point has often been the cause of partial or total failure. Woody fiber in itself is heavier than water, its specific gravity being generally considered as equal to 1.5, water being 1.0. It is, therefore, owing to the looseness of their texture, that so many kinds of timber are lighter than water. The specific gravity of fir timber varies ordinarily between 0.5 and 0.8; the difference arising as often from the varying density of the timber itself, as from the quantity of water contained. As fir timber can, under certain conditions, absorb so much moisture as to become water-logged, or actually heavier than water, its powers of absorption can be calculated from its specific gravity. It can take up as much as from 60 to 150 gallons of water to the load of 50 cubic

feet, the maximum quantity being, of course, an exceptional possibility. Fir and pine, however, frequently contain as much as from 15 per cent. to 20 per cent. of water, after from two to three years' stacking. The question of the pernicious effects of an excess of moisture in the timber at the time of Creosoting, has been from time to time brought before this Institution by Mr. Bethell, by Mr Burt and by the author. Large logs taken out of timber ponds, or sleepers freshly imported, are not in most cases in a fit condition for Creosoting until after having been stacked for from four to six months. The author, in common with most of the earlier operators in this process, has tried various methods for artificially drying the timber. Steam, ordinary and super-heated, currents of hot air, and drying stoves or ovens, have been used for this purpose, but have all, in this country, been abandoned. To subject timber to a dry heat, elevated enough to remove its moisture with the necessary rapidity, will invariably result

in injury to the wood. Timber piles stoved before Creosoting, prove brittle when driven. The action of the air-pump in the ordinary process assists the operation by withdrawing air from the pores of the wood; but it is a mistake to suppose that it has much effect in withdrawing moisture.

These difficulties have perplexed the author for many years. He has recently devised a method by which to get rid of the moisture as part of the timber-preserving process, and without injury to the wood. An experiment easy to reproduce, and which explains the nature of this operation, is made as follows: An ordinary glass flask, in which are placed some pieces of wood saturated with water is connected by glass tubes with an experimental air pump. By working the pump the air is extracted from the pores of the timber, but however efficient the vacuum may be, no perceptible moisture is withdrawn, nor would the water be removed from the wood except by a slow evaporation prolonged beyond

practical limits. This represents the ordinary action of the air pump upon timber in a Creosoting cylinder. If sufficient heat be now applied beneath the flask, the water will become volatilized, and will be withdrawn rapidly in the shape of steam by the action of the air pump. But the wood will be found to crack, and open to an extent which is not desirable. This illustrates the result of applying dry heat.

Now take a similar flask with a condensing apparatus added; moreover, the flask should contain Creosote oil, in which the wet timber is submerged. It must be constantly borne in mind that at the ordinary tension of the atmosphere, the boiling point of the Creosote oils ranges from about 380° Fahrenheit to 760° Fahrenheit, as compared to water at 212° Fahrenheit. These boiling points are, however, lowered, according to a well-known law, by the effects of a vacuum. Let the Creosote in the flask be now heated to 212° Fahrenheit, whilst the air pump is put into operation. The

heat being communicated through an oily medium will not injure the timber, from which the water is volatilized, and drawn out by the air pump. The Creosote oils are not volatilized, as the temperature is far below their point of ebullition. The water is speedily and effectually removed, and the Creosote takes its place.

By the ordinary and well-known process, after the timber has been placed in the cylinder and the air-tight door closed, the air is exhausted from the cylinder, the Creosote is then introduced heated to a temperature of from 100° Fahrenheit to 120° Fahrenheit, when the air pump ceases to work, and the pressure pump is put into operation.

Referring now to the new process, it will be seen that a large dome is placed on the top of the cylinder, to which the exhaust-pipe of the air pump is attached. The exhausting process is continued after the Creosote has been introduced into the cylinder. The Creosote during this part of the operation should not be allowed to rise quite to the top of the

vessel, a free space being preserved, and the dome kept empty, so that the Creosote is not drawn through the exhaust pipe. The Creosote is raised to a temperature a little exceeding 212° Fahrenheit instead of 120° Fahrenheit as heretofore. The exhausting process is continued until all the water is extracted from the timber in the form of vapor, drawn through the dome, condensed by passing through the worm of the condensing apparatus, and collected in the receiving tank, where the quantity extracted can be measured. With charges of very wet sleepers, the author has succeeded in withdrawing water equal in volume to 50 gallons per load of timber, and replacing this water with an equal volume of Creosote by the action of the air pump alone. If necessary, however, the pressure pump can be afterwards applied in the usual way.

A slight additional cost, and a few hours' additional time are necessary for dealing with very wet timber by this process as compared with the ordinary

method. But the expenditure in time and money is not so great as would be required by stoving the wood before Creosoting. If, in the absence of artificial methods, timber be stacked for six months, as it should be, the interest on capital represents a certain expenditure also. The author ventures to suggest that this is not always taken sufficiently into account, in giving out contracts for creosoted timber. Other conditions being equal, dry timber is at a disadvantage in the competition, as far as price is concerned, with timber just landed. Yet a small extra expenditure in this particular would frequently be repaid to the consumer twenty or thirty-fold in the prolonged duration of the wood.

Conclusion.—In conclusion the author would remark that with regard to certain points mentioned in this paper, upon which some controversy has at times arisen, he has been careful to advance no opinion which he has not confirmed, either by the opinions and investigations of eminent authorities, or by careful and

reiterated experiments. Many hundreds of experiments have been in fact carried out at the laboratories of the author's firm at Silvertown during the last five years, with the especial object of investigating the properties of the tar oils and other antiseptics, and their behavior in contact with timber. To Mr. Royle, Mr. Bendix, and Mr. Holmes of the chemical staff of his Silvertown Works he has to return his best thanks for their skilled assistance, and particularly to Mr. Bendix, who has been more especially entrusted with the conduct of these experiments. To Mr. Gabbett he is indebted for the drawings exhibited.

The Treatment of Timber by Antiseptic Methods has been acknowledged by some of the greatest engineers of this country to have been useful to the art of constructive engineering. It may be made even more useful in the future than it has been in the past. All that the advocates for its still more extended development can desire to claim will be, that their methods and investigations

may be seriously examined, and from time to time decided upon, in accordance with the results which science and experience may bring to light.

DISCUSSION.

Sir Joseph Bazalgette, C. B., President, said the subject of the paper was an exceedingly practical one. Timber, in the majority of countries, was the most available material for constructive and engineering purposes, and in some countries it was almost the only material which could be used. The great defect in its use was its want of durability. Anything, therefore, which could remedy that defect, and give durability to the timber, must be a subject of great interest to the engineer. The author in the paper had given the result of thirty-four years' experience, together with his researches into what had been done ages before, and the whole had been placed before the members in a manner showing that he had devoted very great ability and attention to the subject.

Although the author was commercially engaged in that branch of engineering, he was sure the members would feel that the paper had risen considerably above the commercial element, and had clearly shown that science could be, and had been, brought to bear on industrial art, so as to improve it and make it of great value.

Mr. Boulton remarked that the subject of his paper was one which had occupied his attention for many years. He hoped he had clearly explained the analytical investigations by which he had sought for some clue to what was a rather complex labyrinth, namely, the kind of substance which was the best to put into timber for its preservation. He had employed many of those substances, and the conclusion at which he had arrived was that, supposing the substance to be a good antiseptic, whether, as in former times, corrosive sublimate, sulphate of copper, or chloride of zinc were used, or whether creosote oils, there was always a close connection between the durable results of the anti-

septic and the immunity of that antiseptic from volatility in the air or solubility in water. Timber must be exposed to air for engineering purposes, and also to water; in some cases in marine work, it was in the water altogether, and therefore, the antiseptic ought not to be liable to evaporation or to being washed out by the action of the water. He was not there to advocate the use of the creosote of one district more than another, because, commercially speaking, that was a matter that did not affect him. He thought that all honest creosotes made from coal-tar in England were useful for the purpose of preparing timber; but he thought that some of them were more useful than others, because they were more durable. If, therefore, engineers would take the trouble to follow out his idea, and study the different constituents of the creosote oils, remembering which of them were the most durable and the least soluble, that would give a clue to the formation of fresh specifications for the preparation of timber. He did not think that the pres-

ent specifications were satisfactory in all respects. Plate 6 represented the products derived from Newcastle coal, such as was ordinarily carbonized in London gasworks. There was, as had been explained in the paper, a different series of products from the Midland coals ordinarily carbonized in other parts of the country. Taking the same coals—those carbonized in the gasworks—and subjecting them by carbonization to a lower temperature, another class of products would be obtained as had been pointed out by Dr. Armstrong in a recent discussion. It was as well that engineers should bear that in mind, as they were now witnessing an inauguration of a new series of industries, namely, the partial carbonization of coal in coke ovens, partly for the purpose of getting the products direct, instead of through the gasworks. Those other products might be valuable, but they were not the same as far as the preparation of timber was concerned, for they were lighter and more volatile. He had taken the trouble to get some truck-

loads of different coals used ordinarily by the London gas companies; he had carbonized them on a large scale at lower temperatures, and had found that he obtained thinner and lighter oils with a specific gravity of from 930 to 1,030, instead of from 1,045 to 1,060, and he had a different class of products altogether.

Dr. C. Meymott Tidy said it was twenty years ago when he commenced working with creosote, and he was bound to admit that since that time his views had undergone considerable changes; but he supposed there was no great harm in that, for the views of engineers, politicians, and even of theologians, were constantly shifting. The process of creosoting was of a threefold nature. First, there was the physiological action of rendering the wood a poison, so that animals could not or would not attack it; secondly, there was a chemical action, consisting chiefly in the coalgulation of the albumen; and thirdly, there was what he held to be by far the most important action of the three, namely, the simple mechanical ac-

tion. The process of creosoting was practically a choking up of the pores of the wood so that neither air, moisture nor life could get inside. He well remembered the late Dr. Letheby drawing up his original specification. No doubt he was very strong in his belief of the enormous value of carbolic acid; indeed, he regarded it, as the author had stated, as probably the most important ingredient of the tar. In the last specification which he, Dr. Tidy, had drawn up a year ago, and which was now being employed largely, he had laid down three essentials, and as they practically represented the views which he held on the subject at the present time, he might be allowed to refer to them. The first point of the specification was that the creosote should be completely liquid at a temperature of 100° Fahrenheit, no deposit afterward taking place until the oil registered a temperature of 93°. That point was considered very fully. The temperature at which creosoting was performed was about 120°. It did not appear to him to matter one iota

how solid the creosote was (and he was bound to say that from his point of view the more solid it was the better), so long as it was liquid at the temperature at which the creosoting process was done. Seeing that the process was carried out at a temperature of 120°, he thought he was right in specifying that the creosote should be liquid at the temperature of 100°. The next point was (he had left out a specific-gravity clause) that, tested by a certain process, the creosote should yield a total of 8 per cent. of tar acids. He was aware that in an earlier specification drawn up by Sir Frederick Abel and himself about three years ago, they specified 10 per cent., and of course it was only fair to ask him why he had thus degenerated. Having examined a very large number of creosoted timbers that had been prepared for at least a year, he was unable to detect the slightest trace of carbolic acid in them. This fact had also been very prominently and excellently well brought out by Mr. Greville Williams. But although after a short period

there was no trace, so far as he could make out, of carbolic acid in the sleeper, yet the wood continued as sound as ever. It was also a fact that the earlier timbers were creosoted with heavy oils containing only a small quantity of carbolic acid, nevertheless these very sleepers laid the foundation of the success of creosoting at a process. Taking those two facts together, it appeared to him that they had hitherto placed an exaggerated value upon the carbolic acid. He did not wish to be misunderstood. He did not say that the carbolic acid evaporated, nor that it might not undergo certain chemical changes in the wood; he did not know what took place, and that was not the place to discuss the question. It was on the ground, however, he had mentioned, that he had fixed the quantity of the carbolic acid as low as was consistent with obtaining a genuine creosote. In other words, he fixed 8 per cent., not because he regarded 8 per cent. as necessary for the purpose of creosoting, but because he thought from a large number of an-

alyses of London creosote, that by fixing 8 per cent. he should ensure the obtaining a genuine creosote. In the other part of his specification he admitted that he had completely altered previous specifications, namely, in requiring that the creosote should contain at least 25 per cent. of constituents that did not distil over a temperature of 600°. He believed that up to that time almost every specification had required that the oil should contain at least 75 per cent. of matters that did distil over 600°. He entirely agreed with the author that it was to the heavier oils that the success of the creosoting process was due, and it was therefore by the amount of those oils that did not distil over at a temperature of 600° that the excellence of the creosote to be used for creosoting purposes should be determined. It appeared to him to be highly advisable to get the heaviest creosotes for the work, and to insist upon as great a quantity as possible of the creosote being driven into the wood.

Dr. H. E. Armstrong said that, on the

whole, he concurred in the views expressed by the author. He thought that creosoting, instead of being an operation of a threefold character, as Dr. Tidy had stated, was of a onefold nature. Water had to be excluded, because in excluding water everything was excluded which was likely to be harmful. When water was introduced, other things were introduced with it, especially certain organisms which there could be no doubt played a most important part in effecting the rapid decay of timber. He agreed with Dr. Tidy that, mechanically, it was of great importance to choke up the pores, but the object was not so much to choke up the pores as to prevent the perpetual moistening of the wood. When wood was moistened, and was subject to frequent variations in pressure, it necessarily became after a time reduced to a very spongy condition mechanically, and its quality was in that way materially affected. If, therefore, the access of moisture could be prevented an important point was gained. The author had briefly referred

to Pasteur's experiments, which perhaps were not so well known as they deserved to be. He supposed that the experiment to which special reference was made was that conducted with sawdust. M. Pasteur had shown that if ordinary moist sawdust had air passed over it for a few hours, there was obvious evidence of decay afforded by the production of carbonic acid. But if precautions were taken to kill all the organisms attached to the sawdust by heating it, and if it was then moistened with water deprived of organisms, and exposed to a current of air carefully deprived of organisms by filtering through cotton wool, the current of air would pass over it for hours without there being any evidence of the decay of the wood. That was the fundamental experiment upon which the views of chemists with regard to the part played by organisms were based at the present day. With reference to the author's remark as to the difference between creosote, properly so-called, and coal-tar oils, he thought there was a little misunderstanding on

that point. The author stated, "Creosote, correctly so-called, is the product of the destructive distillation of wood, and coal-tar does not contain any of the true Creosote, which has never been used for timber preserving." That was not quite correct, because true creosote contained a considerable quantity of carbolic acid and cresylic acid, which had been commonly regarded as active constituents of ordinary creosote oil. With reference to what was really the active constituent in creosote oils, the remarks of Dr. Tidy met with his approval to a large extent, but he should be inclined to predict that before many years Dr. Tidy would drop his limit from 8 per cent. to 6 per cent., and perhaps eventually sink it altogether. It was very much to be hoped that that would be the case, because he thought that engineers were using a material for creosoting that ought not to be employed for that purpose, and probably the carbolic acid was practically of very little use. He did not think that the coagulation of the albumenoids to which reference had

been made, took place to any large extent, or was an essential part of the process. That was, he thought, the only part that could be assigned to the carbolic acid. There could be very little doubt that, within a comparatively short time, either by evaporation or by being dissolved out, the carbolic acid disappeared. It was not there in any form, but actually went away. There was no probability that it would be fixed in such a way as to escape attention and detection by the tests employed by Dr. Tidy and Mr. G. Williams. He was inclined to think the action was mainly a choking action as described by Dr. Tidy, the access of water to the wood being prevented. It was therefore simply a question of obtaining an oil which would do that in the best possible way, which could be introduced into the wood with the greatest readiness, and would remain in it under ordinary conditions, for the greatest length of time; and if, as the author had said, with the oil which would exercise that action engineers could introduce substances like acridine and other

compounds of a poisonous character, so much the better.

Professor A. Voelcker remarked that, as had been pointed out by the author, the antiseptic treatment of timber had almost entirely superseded former methods, and justly so, for on the strength of past experience there could be no question that, when properly carried out, the impregnation of timber with crude creosote was the most efficacious, the least troublesome, the most persistent, and the cheapest process that could be adopted. He gathered from the paper that the author was rather inclined to think that chemists had attached too much importance to the presence of carbolic acid in creosote oil. He had pointed out that certain alkaloids in coal-tar possessed antiseptic properties, even in a higher degree than phenol, and had suggested whether it would not be desirable to modify somewhat the specifications issued by the Crown Agents for the colonies, by the War Office, and other public bodies. Professor Voelcker agreed tha

the heavy tar-oils were extremely useful, and perhaps more so than the light tar-oils, for preserving timber intended to be used for railway sleepers. He could not go so far as Dr. Tidy, who had suggested (he granted somewhat vaguely) that chemists had attached far too great importance to the presence of carbolic acid in crude creosote. But he would go as far as to say that for preserving well-seasoned old timber, it did not, perhaps, matter so much whether there was a high percentage of carbolic acid in the creosote, as it mattered that there should be present in it a high percentage of the oils which passed over on distillation above 610°, because, as Dr. Tidy had pointed out, the effect of these tar compounds was to close up the pores of the timber, to render it impervious to water, air, and other debasing influences; being at the same time in itself, comparatively speaking, an imperishable substance, like all pitchy products when completely dried. But it should be borne in mind that it was requisite not only to preserve

well-seasoned old timber, from which the moisture was expelled almost completely, but that of late years a great deal had been done in preserving telegraph-posts, gate-posts, wooden fencing, hop-poles, and the like, for which sapling-wood, or at any rate young wood, was used. There was a great deal of difference in the chemical constitution of the two kinds of wood. Sappling-wood was more or less filled with sap, and in the liquid which circulated in it there were perishable substances belonging to the class of albumenoids, which acted as ferments, and caused otherwise imperishable substances to decay. The primary causes of decay of green wood were unquestionably the albumenoid substances; and all the older processes, such as the corrosive sublimate, or kyanizing plan, or the impregnation with other metallic salts, were based on the principle that by those metallic salts, notably by the bichloride of mercury (corrosive sublimate), the albumenoids were precipitated, and rendered insoluble and incapable of acting

as ferments. In green wood also, the celluloise was in a more tender condition than in old wood, where there was a larger proportion of incrusting matter; there was, therefore, a greater reason for preventing the first state of decomposition; and hé questioned whether creosote, which was sometimes extremely poor in carbolic acid, was the proper material for preserving wooden structures of the kind he had mentioned. No doubt there was a good deal to be said in extenuation of the qualities of creosote, for the process of preserving wood in open tanks, was sometimes unskillfully—not to say carelessly—conducted; but, making all allowance for the imperfections of the methods for preserving wooden poles in that way, there could be no doubt that sometimes creosote answered remarkably well, and in other instances the same process tended to make the wood more perishable than it would have been had it not been creosoted at all. That seemed to be a contradiction, but according to the evidence of those who had carried on the

process with more or less success for fifteen years or longer, the same kind of creosote would answer extremely well for preserving hard timber used for railway sleepers, while for young wood it did not answer the purpose. He had found, from the examination of samples which had been sent to him, that there were great differences in the composition of different creosotes. Not long ago he had received a sample which yielded, on distillation from the boiling point up to 610°, only 39 per cent. of distillate, containing no more than 3 per cent. of carbolic acid; while another sample yielded 14¾ per cent. of a watery liquid with a little light oil, the water being strongly ammoniacal; and it was well known that any ammoniacal water left in the creosote was extremely injurious to the timber. The same sample only yielded 47½ per cent. of distillate; including 4¼ per cent. of crude carbolic acid. In a third sample he found only 5 per cent. of carbolic acid. He ventured to think that creosote containing as little as 5 per cent. of crude car-

bolic acid was not a good liquid for preserving immature wood, simply because it was not strong enough to precipitate or render ineffective albumenoid substances. Even Dr. Tidy, in the recent modifications of his views, still recommended that the creosoting liquid should contain as much as 8 per cent. of crude carbolic acid. A great deal had been said about the specific gravity of the creosote. He confessed that he did not attach very great importance to specific gravity, but he did attach great importance to the presence of a fair percentage of phenol, or crude carbolic acid, if it was wished to preserve green wood, such as that used for telegraph posts or hop-poles; because it was essential that the first tendency to subsequent decay should be counteracted, and that could not be done without the introduction of a sufficient quantity of carbolic acid. In the case of hard timber the main object was to fill up the pores. There was not so much albumenoid matter present, and the timber would keep fairly well if moisture was excluded; that was

effected by heavy tar oil which filled up the pores, and rendered the wood very hard, so that there was not the same necessity for the presence of carbolic acid. He could even understand that if crude creosote contained a very small quantity of carbolic acid, as in the case he had mentioned, and if there should be a large proportion of the more solid constituents of creosote, the pores externally at any rate would be closed up, and the same thing would take place by painting or pitching unseasoned wood; the solid constituents closed up the pores of the outer layers, introducing nothing to render the albumenoids ineffective as a ferment, so that the moisture was kept in, and in that way decay was actually hastened, whereas if free passage were allowed, the wood would be washed out and would keep longer. Engineers knew from experience that green wood, when thoroughly painted or pitched, decayed more rapidly than wood in its natural state. In order that the point might be settled he would suggest that some experiments be tried with

creosote containing various proportions of carbolic acid, not with reference to the preservation of railway sleepers, but of younger wood. Strictly comparative experiments should be made with crude creosote, one sample containing 5 per cent., another 10 per cent., and a third 15 per cent. that being the usual range of carbolic acid in commercial creosote. Some well-conducted experiments in open tanks with creosote of various strengths would, he thought, finally settle the question. He could not help thinking that it would be requisite for the proper carrying out of the process that there should be something like 10 per cent. of crude carbolic acid in the creosoting liquid; at any rate, without further information on the subject, he should be disinclined to recommend anybody wishing to preserve hop-poles or telegraph posts to use any liquid containing a less amount than he had mentioned.

Mr. H. K. Bamber said it appeared to him that the whole secret of the paper was to be found in the paragraph, "By

the light of the evidence now accumulated, it may be advisable to review the question as to the relative value of these various bodies contained in the heavy oils as regards the preservation of timber. Some of them are becoming valuable for other purposes. Which of them should the engineer retain for injecting wood?" Carbolic acid, if left in creosote, was worth 2d. a gallon, and if taken out from 4s. to 40s. per gallon. according to the state of purity. The author's idea appeared to be that nothing should be left in the creosote which it would pay him better to take out; in fact, there should be nothing left that was worth more than the proverbial 2d. He did not appear to see the difference in our color between the two pennies and the two sovereigns. The difference in the town-made tar and the country tar did not arise so much from the difference of coal used as from the degree of heat used in making the gas. In London it was desired to obtain a harder coke that would do for engines, and for that purpose a much higher

temperature was used, and the most luminous portion of the gas first formed was decomposed on coming into contact with the sides of the red-hot retort, the result being gas charcoal, naphthaline, and a gas of less illuminating power. With regard to Dr. Letheby's specification, that very specification was advocated and recommended by Messrs. Burt and Boulton, but then carbolic acid had not become so valuable when separated. Now the specification recommended was drawn up by Dr. Tidy, and if the author could get his views adopted there would soon be a very tidy specification to work from. The author had mentioned some experiments of Dr. Tidy's with naphthaline injected into wood, but he had given no facts or data, merely expressing his own opinion. Again, the experiment was not similar to the exposure of creosoted sleepers, which were not subjected to a temperature of 150° Fahrenheit in a closed vessel. He would give the results of two experiments that he had made in 1882, one with country oil, condemned by the author, and

one with Mr. Boulton's own oil, full of naphthaline. He took a piece of wood (deal), 3 inches by 3 inches by 8 inches, and dried at 230° Fahrenheit, until it lost no more weight, so that there was no water left in it to cause loss. He then kept it in a vessel containing the author's London creosote, heated to 180° Fahrenheit, having a weight on the wood to keep it under the creosote. It took up 1,020 grains, after being wiped from excess of creosote outside. It was then, on February 7th, 1882, placed on a mantelshelf, where the temperature was never above 70° Fahrenheit, and generally between 40° and 50°. It was repeatedly weighed, and the loss was constant until June 5th, 1882, when it had lost 487 grains, equal to 47.75 per cent. of the creosote put in. Now, as there were only 10 per cent. of crude tar acids in the creosote, what was it that made up the 47.75 per cent. loss? Water there was none. The loss arose chiefly from evaporation of the naphthaline. At the same time he treated a similar piece of wood, 3 inches by 3 inches

by 6 inches—2 inches shorter—dried at the same temperature, until it ceased to lose weight. It was then immersed in country oil, specific gravity 1,045, and kept under the oil by a weight, but without applying heat. It absorbed 1,788 grains of the creosote, so that the wood, which was a quarter smaller, took up, actually, in cold, more than double the quantity that the other piece did of the author's oil at 180° Fahrenheit. The piece was placed side by side with the other on the mantelshelf, and in four months it had lost 575 grains, or 42.33 per cent. of the oil taken up. But that was not fair to the second piece of wood, for it was so saturated that some of the oil drained out on the mantelshelf, and of course contributed to the loss of weight, although it was not by evaporation. The oil contained about 20 per cent. crude tar acids. Those were plain facts, and showed that the author's contention "that country oils are not good for creosoting timber because of their instability" was contrary to fact.

The beautiful white substance, naphthaline, was liable to sudden changes. It might at one moment be a black dirty-looking substance, and, by the application of a moderate heat, it became volatilized and condensed into a lustrous substance. The author, by Dr. Tidy's experiments, had tried to make out that it was not volatile. Camphor, although it could not be volatilized by heat without decomposition, yet it was well known that a piece of camphor, even when wrapped in paper or any porous material, would soon pass away by evaporation; and it was so with the naphthaline. Many attempts had been made to prepare tar colors, &c., from naphthaline, but as yet without success; it was worth nothing (except in small quantities in the albo-carbon gas-burners) when separated from the creosote; and that was the reason why it was so valuable, according to the author, in the creosote. But if ever, by chemical research, naphthaline became as valuable as carbolic acid, it would then become so volatile as to escape from the

creosote altogether, and chemists would be asked to reconsider their creosoting specifications. As to the solubility of carbolic acid in water and alkaline solutions, which the author said was a disadvantage, he maintained that it was an advantage, for it enabled the acid gradually to dissolve in the water and sap, and thus get into the substance of the wood and prevent decay, while the other portion of the creosote remained like beauty, only skin-deep. To say that because carbolic acid could not be found in creosoted sleepers after twenty or thirty years, and that therefore it had nothing to do with stopping decay, was absurd. It might as well be said that a few days after a large fire only one or two policemen were found and no fire-engines, and that therefore the policemen put out the fire and not the engines. Carbolic acid was an oxidizable substance, and would protect the wood from oxidation or decay. It instantly prevented decomposition, and destroyed the life of the germs which caused decay, being also poisonous to

most insects. Dr. Tidy had mentioned the number of analyses he had made, and how long his experience had lasted. Mr. Bamber might therefore be allowed to state that he had tested samples of creosote for the last twenty-five years, and had practical experience in the process of creosoting. It was his opinion that to creosote timber properly the creosote tank must not be only the "waste tub" for distilling works. It was easy to get good country oil with 18 to 25 per cent. crude tar acids, yielding no deposit of that volatile substance, naphthaline. He had met with some samples of so-called creosote that contained nearly half their bulk of filth, consisting of charred oil, &c., he presumed the residues from anthracene manufacture, yet when the creosote was rejected every effort was made to induce the belief that it was some of the best creosote.

Dr. Albert J. Berneys said that no on could doubt the conclusion that the sut stances preferred should be germ ex

cluders as well as germicides, and those contained in the oils which were heavier than water. His contention would be to retain, at least in part, and to the extent of 2 per cent., the carbolic acid as well as the naphthaline and the alkaloids. The arguments in favor of carbolic acid were very strong. Where the creosoted timber was covered up in the ground the solubility in water assisted in diffusing it somewhat in the earth, and thus extended its sphere of action. Nor should that solubility be exaggerated. In a dry soil the loss could only be by heat, and that would also affect other ingredients. It said much for the durability of carbolic acid that, in spite of the employment of heavier types of tar-creosote in early days, it was distinctly present in many cases recorded in the experiments of Mr. Greville Williams. In one specimen wood creosoted thirty years, distilled with water, a distinct reaction of phenol was obtained in a case where most of the oil and all the naphthaline had disappeared. In another, creosoted thirty-two

years, the phenol reaction was very distinct. In a third, creosoted twenty-nine years, the phenol reaction was very strong when distilled with acid, but was also distinctly present in a free state; whereas there was no naphthaline and very little oil. In cases where no free phenol was found, it was discoverable in combination. The power possessed by phenol for coagulating albumen could not be exaggerated. He would not describe his own experiments; but in his hospital work he was very familiar with the high antiseptic power of carbolic acid. The experiments of Mr. Greville Williams with the white and yolk of an egg only showed that the alkaloids of the tar-creosote, weight for weight, were equal to the carbolic acid as germicides, but certainly no more; and that the $\frac{1}{1000}$th part of phenol bore no relation to the amount of albumen present. If all the albumen had been coagulated it would not have putrefied. For Mr. Williams further stated that 1 per cent. of phenol and 1 per cent. of alkaloidals

were of equal value. He believed in the coagulation theory by phenol of the albumen of the wood, but unless enough was used it was as with disinfectants. If he had a quantify of hydrogen sulphide in the air of a room, and he only used enough chlorine to unite with one-half of the hydrogen present, where would the disinfection be? It was the worst of disinfectants that generally they could not be used in sufficient quantities. The benefit of them was (as Miss Nightingale had said) that it was necessary to open the window when they were used. It was the same with phenol. If he did not coagulate the albumen, of which there was but little in the wood, he failed. But the phenol had the property and the additional advantage of volatility. It took a long time for even the free phenol to evaporate, so much was it protected and shut up by the oil and naphthaline in the tar-creosote. And he believed that not only was carbolic acid more potent as an antiseptic than any other constituent of the tar-creosote, but

that it was present in larger quantities than the alkaloids which, according to Mr. Williams, were equal to it weight for weight.

Mr. W. Foster regarded the question brought forward by the author, as to the value of alkaloidal substances, as a very important one. In a paper which he had recently read before the Institution, he had remarked on the possibility of some of the nitrogen, which he was then in search of, being in tar in the condition of alkalodial bodies. The author had mentioned five or six of those nitrogenous bodies, and there were probably others. The recent investigations of chemists had shown that pitch itself contained an appreciable amount of nitrogen. Acridine, of which an example had been given in the table, contained the lowest percentage of nitrogen, and had the highest boiling-point. Having regard to the pitch, it was possible that there were other nitrogenous bodies which had a still higher boiling-point, and a lower percentage of nitrogen than in the case

of acridine. The quantity of those alkaloidal substances in the tar was very small. There was no information as to their relative proportions; and as the percentage of nitrogen varied from 17.7 to 7.8, it would not be wise to specify how much of those bodies was present in the tar. He thought he might say that there was not more than from ·3 to 4 per cent. If, therefore, they had any value in the preservation of wood, their effect must be very powerful. He was inclined to look at the question of the preservation of wood by the aid of some facts which were a little outside the subject. He might be pardoned for referring to the corrosion of iron. Iron could remain permanent in dry oxygen, in pure water, or in pure carbonic acid gas; in any two of those it remained permanent; it was only by the conjoint influence of the three that corrosion was effected. Pitch, he believed, was the best preservative of iron that was to be had, and if applied to a clean surface free from oxide (rust), it was impossible to say when the surface

of pitch would fail to protect the iron. He was of course speaking of the continuity of surface being preserved. Pitch was a substance of a most permanent character, being almost destitute of any chemical attributes; if, therefore, the cellular structure of the wood could be thoroughly permeated by it, as long as the continuity was perfect, it would be preserved. Of course, that could never be fully realized in practice. In the case of green wood, the question arose as to the coagulation of albuminous matter. No need to go far afield to get plenty of instances showing that if water and impure air could be kept out, the preservation would be prolonged. The author had referred to the experiments of Pettigrew; but the inference he had drawn was not the only one. If albuminous matter was dried, it could be kept as a horny substance for an indefinite length of time. A piece of glue could be preserved intact in the same way. If white of egg or glue were moistened and exposed for a certain time, it putrefied.

The inferences deducible from Pettigrew's experiments could, he thought, be traced to the removal of water from the muscle (the heart), which had been the subject of the experiments. The whole thing might be summed up in the gravedigger's reply to Hamlet, "Water is a sore destroyer of the dead body."

Mr. W. Carruthers thought that the botanical aspect of the question should be at the basis of the inquiry; for without a proper appreciation of the circumstances under which vegetable tissues were destroyed, it was impossible rightly to appreciate the means by which that destruction could be prevented. While he agreed with much that had been said, he felt bound to differ from a great deal that he had heard. He acknowledged the great importance of pitch for preserving the external surface of wood. But wood decayed not only from chemical agents, air and water; but much more from the action of parasites. He could easily see that if a body was entirely protected externally by pitch, it would be

preserved from chemical changes, but not from the more injurious and dangerous attacks of fungal parasites. They were developed from spores, and the attack might be made through a flaw or crack in the wood. When the wood was exposed to the desiccation of the air, flaws continually appeared, and wherever a spore could get access, there would begin development of the mycelium or root of the fungus, which penetrated the wood wherever nutritious materials were supplied through its whole course; so that unless the wood was preserved by some substance which would prevent the life of fungi, its destruction was certain. He exhibited a specimen of wood the date of the creosoting of which was not known, but it had been used in a hurdle for at least ten years. The lower creosoted portion, embedded in the earth, did not show the slightest injury; but the upper part, exposed to the air, and cracked, had been attacked from the outside by minute vegetation. Some of the spores had obtained access to the interior, which had not been

antiseptically preserved, the fungi had enormously developed, and the interior had been destroyed by them. The same thing had occurred in the case of two specimens of telegraph poles. The exterior of the specimen which he exhibited had been fairly preserved, but the interior had been destroyed. It was remarkable that the interior was colored by the injection of what he supposed he must call creosote; but it had not been sufficient to serve as an antiseptic, as it had permitted the free growth of fungi, which ramified through the base of the pole and completely destroyed the cellulose or lignine, leaving it a fragile skeleton. It appeared to him that what was needed was a sufficient impregnation of the wood with creosote, and with that element in it which was destructive to vegetable life. He did not know from experiments what that element was, but he did know that there was an element in crude creosote that was extremely destructive to vegetable life, viz., carbolic acid. Not, however, in all strengths, for Koch, a distinguished

German mycologist, had found that certain liquids, with 5 per cent. of carbolic acid, would support fungi; so that the presence of a small percentage was not destructive to vegetable life. That was extremely important in relation to the observations of Prof. Voelcker. Another specimen from a telegraph pole had been completely destroyed by a fungus (*Reticularia*). There was on one side a yellowish dust, consisting entirely of the spores of the plant. But in a specimen from a hurdle, which had been in use since 1861, when it was creosoted, the exterior, although it had no coating of tar, still exhibited the minutest marks of the tools employed upon it, and the interior, which was completely saturated with a brown substance, was as good and fresh as if it had been creosoted yesterday, without a particle of fungus. There was a little greenish vegetation on the outside, but it was epiphytic, and not injurious to the wood; there was no fungal vegetation whatever. The wood had been enormously increased in weight, and he had

ascertained microscopically that there was no deposit in the interior of the cells. The whole of the lignine and of the secondary deposits had been colored by that material, so that the tissue had been completely altered. It appeared to him that there had been a new combination through the injected material, producing an antiseptic condition of the wood which was fatal to the fungi. There was a little free carbolic acid crystallizing in the interior of the cells, but it did not seem to him that that was the explanation of it. He should be glad if those who were conversant with the chemical aspect of the subject, would inquire into the real nature of the change which had produced the discolored and altered condition of the lignine. In his opinion nothing had been introduced for preserving timber that could compare with the creosote used in the specimen he had exhibited, which had been exposed to the air nearly twenty years, and yet the ragged edges of the chips on the outside had not even

been touched by atmospheric or other destructive agents.

Mr. Henry Maudslay observed that, in the case of Old London Bridge, the decay of the timber piles of the piers varied according as they were constantly under water, or exposed to water, air, and sun; or exposed especially to salt water or to fresh water on the rise and fall of the tide. There were many combinations of circumstances that tended practically to destroy timber, and it was therefore most desirable to ascertain the exact position that would be occupied by a solid pile driven into the earth to support a strucure—whether it was to be exposed to the constant action of the water below in the earth, or to a change in the rise and fall of the tide, or to the influence of moisture gradually attacking it above the highest spring-tide level. On the Arran and Snowdon mountains he had been lately excavating soil in order to form a reservoir, and had come across some of the largest roots of red pine timber that he had seen in that locality. There were no

trees on the mountains at the present time, and it must have taken many years for the timber to have grown at that elevation—1,200 to 1,500 feet above the level of the sea. The timber was of a magnificent character; these roots had been submerged perhaps centuries. The roots had been found *in situ* covered with a layer of disintegrated earth saturated with water from the copper mines. They had been preserved in that way by nature, but now that they were being exposed to the air, they were in some cases beginnin to crumble away. The props and supports in old workings of copper mines were preserved, and would burn with great difficulty. Since the Royal George had sunk in 1782, all the timber had become saturated with sea-water, which was so destructive to the cast-iron cannon, that they were made as soft as plumbago; but salt water had a great effect upon the preservation of the oak wood, making it quite green. The timber was so hardened that all the pores seemed to have been filled with some material that was suit-

able to its preservation. It still retained that quality, as shown in the case of a billiard table made for Her Majesty, and by another now in his late father's house at Norwood. This table had been made by Thurston in 1860, from the wreck which was raised in 1841. With regard to the decay of iron, he might be permitted to mention that Queen Anne's statue at St. Paul's cathedral, was one of the finest of London specimens of decay of iron that engineers could examine. It consisted of cast iron, wrought iron, lead, and stone, all of which were mouldering away by the action of nature, the character of the air, and the water. The whole of the iron work was a magnificent specimen of age and deterioration. If chemists would examine the question as to effects produced upon timber subjected to the continual action of water and its components, or to the rise and fall of the tide, whether salt or fresh, or only to the effects of a certain amount of moisture, as in the case of railway sleepers afterwards dried by the action of the sun, the practical results of

their investigations would be of great value.

Mr. E. A. Cowper said he understood that an examination of the old pieces of timber successfully creosoted that had been exhibited, showed they were not at present protected by tar acids, and if they had had any in them in the first instance, it had long ago evaporated. The unsuccessful telegraph pole exhibited by Mr. Carruthers, from which a specimen had been taken, had evidently not been put into a creosoting cylinder, for it had a mere slight covering of creosote outside. Hop-poles were often put into an iron pan with a fire under it and made hot, and there could be no doubt that steam came out from the water evaporating, and the very action of which the author had spoken took place to a slight extent. The piece of wood that was cut to a taper had a little creosote in its end, but on its sides the creosote did not go in $\frac{1}{16}$ of an inch, it was merely paint on the outside; where the mortise-holes had been put through the post the spores had

entered and attacked the inside. The effect of a spore getting into a piece of timber that had been preserved only on the outside surface was no argument against the preservation of timber by creosote. The piece from the Victoria Dock fence, which had been well creosoted, had been preserved, and was as sound as it was twenty-nine years ago, when it was put down. The creosote had gone to the middle of the wood and protected it. The other specimen had not been preserved, and, therefore, it was rotten. A very extensive series of experiments had been carried out by Mr. Charles Coisne, and they were of a very instructive character. Samples of creosote had been taken from England, Scotland, Belgium and France, showing 15, 15, 8 and 7 per cent. of tar acids, and there was a fifth specimen of heavy oil without any tar acid. Other mixtures were made by putting in an extra quantity of tar acids, except in the case of the one kept without acid, and the result showed that where the heavy oil was

used, the wood was preserved in the best manner, whilst those samples of wood preserved with creosote, having an extra dose of acid, were not so well preserved, and that which was unpreserved was entirely rotten. He had gone to Silvertown to examine the apparatus to which reference had been made. There were a number of pipes in the bottom of the creosote cylinder with superheated steam in them. When the timber had been put into the cylinder and warm creosote run in upon it, the temperature was gradually got up, and the water was as effectually driven out of the wood by evaporation as would be the case if water was put in a boiler with a fire under it and kept without any fresh supply of water. A temperature of 220° or 230° would evaporate every particle of moisture out of the wood, more especially when a vacuum was put on. He might mention that the vacuum should not be turned on suddenly, otherwise the creosote, steam, and water would all boil over. Water was deposited in a vessel in connection with

the condensing pipe, together with some light hydro-carbons. The creosote supplied to the creosoting vessel being heavy oil, would not commence to boil until about 392°. London creosotes contained about 4 to 7 per cent. of tar acids. He had himself tried some experiments in coagulating and precipitating albumen, and he found that considerably less than 2 per cent. of carbolic acid in the creosote would precipitate the largest amount of albumen found in wood, so that there was amply sufficient carbolic acid in the London creosote for that purpose. Not only was the albumen coagulated by the two per cent. of carbolic acid, but by the mere fact of its being boiled. If an egg was boiled for a short time the white would set, and in an hour or two it would be very hard. After the vacuum had been on for a sufficient time, and the whole of the water and moisture withdrawn from the timber, the cock was turned, and the pressure put on with pumps up to 120 lbs. to the square inch. Not only did the pumps

put on the pressure and force the creosote into the wood, but directly the temperature was lowered a little, steam condensed, and there was a vacuum in every pore of the wood. The whole of the wood was made a condenser; in every pore that had previously contained water there was a vacuum, so that the creosote went in, and, besides that, there was the pressure of 120 lbs. to the square inch. At the works he saw a whole range of tanks, following one after the other. He thought the method was a very practical and mechanical one. There could be no doubt about the creosote thoroughly entering the timber. He thought the thanks of the members were due to the author for the admirable way in which he had developed the subject. The only thing wanted was a sort of skeleton specification for their guidance in the future.

Mr. W. H. Preece said that as the behavior of certain of Her Majesty's telegraph posts had been called in question, he ought to say something in their be-

half. For the past thirty years he had devoted all the attention and skill that he could command to the inquiry as to the best modes of preserving, timber. In the telegraph service of the country many millions of poles had been preserved in various ways, and one of the methods—that explained by the author—had proved to be the survival of the fittest. A great deal had been said as to the various causes of decay. Reference had been made to chemical and physiological causes, but there was a third cause, which might be called mechanical, of the decay existing at the "wind and water" line, or the ground line, where the timber was exposed to incessant changes of moisture and temperature. A careful microscopic examination showed that the process of decay was a purely mechanical one, that the wood disintegrated by a process of bursting. The fibers appeared to be minute boilers, and the change of temperature produced evaporation, minute explosion, and rapid deterioration. It was a simple thing to

meet the chemical cause by the insertion of salts of various kinds, and it was possible to meet the physiological cause by antiseptic treatment; but the mechanical cause could only be obviated by coating the fibers of the wood with waterproof material, and filling them with a thick, viscous mass like creosote in its best form. In 1844 the first line of telegraph was constructed between London, Southampton and Gosport, and the posts were made of the best Memel timber, preserved by the burnettizing process, simply impregnating the wood with zinc chloride. In 1857 he made a personal observation of a great part of the line in different grounds, and found that in sand about 40 per cent. of the posts had gone, in clay about 33 per cent., and in chalk about 28 per cent. In 1860 he found that the proportion was much greater, and in 1871 they had all failed, so that they had to be removed. The burnettizing process materially added to the life of the pole without rendering it indestructible. Kyanizing was tried to a

small extent, but the poisonous character of the salt deterred him from carrying it further. The favorite process about twenty years ago was that of boucherizing. The authorities had purchased whole forests, and in the middle of them established the boucherizing process, by which they had succeeded in lengthening the life of timber considerably. While the life of an average telegraph pole unprepared was about seven years, the life of a boucherized pole was about fifteen years. In 1848 a line of poles was erected from Fareham to Portsmouth, a distance of about 20 miles, and all the poles, three hundred and eighteen in number, were creosoted by Mr. Bethell. It 1861 he examined them all *in situ*, and only two showed the slightest trace of decay, and they had begun to decay at the top. In 1874 he had them again examined, and every pole was sound. Last year, owing to the requirements of the service, and the necessity of increasing the number of the wires, the line of poles had to be taken down,

and although they had been put up in 1848, they were as sound as when they were first erected. About the year 1861 the question of the proper mode of preserving timber was one of great consequence. The authorities were not satisfied as to which was the best, boucherizing or creosoting, and consequently, as the Yeovil and Exeter line of the London and South-Western Railway Company the poles were put up alternately: first a plain pole, next a boucherized pole, and next a creosoted pole, the line extending about 40 miles. In 1870 he had them carefully examined, and it was found that of the plain poles that had been up ten years not one existed, all having decayed; while of the boucherized poles 30 per cent. had gone, and of the creosoted poles not one had decayed. The result was that the Government had decided for years past to creosote all their poles. He did not remember the exact specification thut was used. At present the millions of poles existing in the country were all creosoted. It was

true that some of them had failed, but, as Mr. Carruthers had pointed out, there was creasote and creosote. There were unreliable firms, and others in whom confidence could be placed; there were inspectors who could be trusted, and others who could not. There were poles about the country supposed to be creosoted that were rotten; and it had been found that those particular poles had not been inspected, and that they had been hastily and improperly impregnated. He could state, as the result of thirty years' experience, that he had never seen a case of a properly creosoted pole showing the slightest sign of decay.

The reply of Mr. Boulton upon the Discussion and Correspondence is given at the end of the Correspondence.

CORRESPONDENCE.

Mr. A. Bouissou, of the Western Railways of France, stated that in 1859, on the line from Rouen to Dieppe, sleepers creosoted by the Bethell process had been adopted for the first time. These

sleepers were of beech. They had been creosoted in England in the works of the author's firm, and when an examination of them was made twenty years later, on the occasion of the Paris Exhibition of 1878, it was shown that not a single one of them bore the slightest trace of decay. Since 1864, the railway company of which he was engineer of the permanent way, had adopted creosoting for their sleepers, and from that date they had applied it to about five million sleepers, of which at least three million and a-half were of beech wood. In these latter, as in the trial sleepers of 1859, no sign of decay has as yet been distinguished, and the lasting powers of the sleepers seemed only to be limited by the wear and tear to which the materials were exposed. Beech wood placed in the ground, without having been prepared, completely decayed at the end of two or three years, which rendered impossible the use of that wood unprepared in the form of sleepers. Also sulphating, employed for a long time for beech sleepers, not having

given the good results expected, had been abandoned by all the French railway companies.

The employment of creosote for the preservation of sleepers had given every satisfaction, and its use had only been limited at certain periods by the difficulty sometimes experienced in procuring a sufficient quantity of creosote. As regarded the quality of the creosote, he simply required that it should contain 5 per cent. of phenic acid.

Mr. W. A. Brown remarked that a preserving process, of which much had been said and a great deal expected by engineers a few years ago, had been referred to in the latter part of that portion of the paper devoted to "Apparatus for Timber Preserving." This process was Mr. Blyth's system of "Thermo-Carbolization," which had been carried out by Messrs. Conner & Co. at their works at Millwall, when a large number of sleepers had been prepared for some of our railways, together with telegraph poles for them and for the Post Office. It be-

came his duty, about four years ago, to inquire into the subject, and he made an investigation into the different stages of the process at Messrs. Conner & Co.'s works, which led him to the following conclusions:

1st, that the strength of the wood was impaired through some of the celluloise and its incrusting materials being carried off in the form of pyroligneous acid by the superheated steam.

2d, that the peculiar "Creosote mixture" used as part of the process, contained so large a proportion of water that it was not at all likely to act as a preservative of the sleepers to which it was applied.

It would be interesting to hear now how the sleepers and poles thus prepared had actually lasted in this country. In Austria the experience of Mr. Seidl, and in France that of the author, as recorded in the paper, appeared to confirm the conclusions at which Mr. Brown arrived in the course of his investigations; but so far as he was aware, there were

no published results as to the process in England.

Mr. John Cleminson observed that the question of preparing timber against decay was occupying more attention now than formerly. It was therefore to be regretted that the author had not referred in detail to many good processes with the above object in view, namely, that of Sir John MacNeill, Gardner, Beer, Blythe, and others. The author's remarks in reference to carbolic acid as an antiseptic would lead to the idea that it was necessary the acid should remain when injected; such was not the case, nor was it necessary. The mere fact of its presence (the most powerful antiseptic known), with superheated steam, was all that was required to produce coagulation of the albumen, and so to render preservation practically complete. With the old process of creosoting, the surface exteriorly only was preserved, the interior if unsound decayed uninterruptedly. All depended upon the selection of the timber. No amount of

creosote would avail to save its destruction ultimately, if the interior was not sound. Where sleepers were adzed, the greater part, and in many instances the whole of the part, penetrated by the creosote was cut away, thus leaving the interior open to destruction from damp and other causes. The same disadvantage was experienced in the case of piles, when the ends were pointed for receiving shoes after creosoting. With carbolic acid once in contact with the albumen, and in the event of any interior unsoundness, the coagulation arrested decay, and prevented it from spreading, by entirely enclosing the defective part or parts. Combined when necessary with an outer application of creosote, thorough soundness and preservation internally and externally were thus secured. Blythe's process was a double process. The object, preservation internally and externally, in the case of sleepers and piles, was most effectually obtained by carbolizing the interior, and creosoting the exterior. A result had been obtained that had placed

this process foremost with French engineers for several years, and it was now largely used by them. In England where used it had met with much favor. The author of the paper was employing this process in France.

Mr. Richard Cowper remarked that the value of creosote for preserving timber depended partly on the mechanical effect which it had in excluding from the pores of the wood air and water, and the germs of destruction which they contained, and partly on the power possessed by certain of its constituents of destroying those germs. For the purposes of germ-exclusion, it was generally admitted that the heavier portions of the creosote, from the less degree of solubility and volatility which they possessed, and their property of solidifying at ordinary temperatures, were the more efficacious. As regarded the germ-destroyers, the phenols and the alkaloids alone need be considered. Phenols, namely carbolic, cresylic, and other acid bodies occurring in creosote, had long been known to possess

remarkable antiseptic properties, but they were easily soluble in water, and comparatively volatile. Much stress had been laid upon their power of coagulating albumen, but it had been shown that no stable chemical compound was formed, and that the albumen thus coagulated might be freed from the phenol by washing with water, when it would decay. It had been shown by the experiments of Coisne, Greville Williams, and the author of the paper, on pieces of old creosoted timber, that in many well preserved specimens no phenol can be detected by the ordinary test, whilst in most cases they had found naphthaline, and in all cases oils of the heaviest character in considerable quantity. It had been shown by Mr. Greville Williams that all the old timbers examined by him contained a considerable amount of alkaloids, and his experiments proved not only that these alkaloids were powerful germicides, but that they were more powerful than phenol. They were at the same time much less soluble and volatile. Evidently if creo-

sote containing a high percentage of phenol were required, it could not contain so high a percentage of the heavier constituents, which were those possessing the greatest value as germ-excluders. At the same time, some of the alkaloids which had been shown to be of more value than phenol as germicides would be removed.

Mr. W. Langdon remarked that in 1874 a paper by him upon the subject had been read before the Society of Telegraph Engineers, in which he warmly advocated the employment of creosote in preference to any other preservative for timber, and he had since seen no reason to alter the views expressed on that occasion. Of late years, however, the appearance of the timber so treated had suggested the belief that the oils now employed did not contain that amount of tar or other heavy compounds which was apparently possessed by the creosote supplied in the earlier eays. His attention in the application of creosote to timber had been more in the direction of telegraph poles

than otherwise, which class of timber was much more exposed to the weather than were railway sleepers, and which might in consequence be accepted as affording a more complete test of the value of the oil than did railway sleepers. These to a great extent were buried in the soil, and had but one side exposed to the influence of the atmosphere. Of late years numbers of the poles had presented anything but the appearance of a well creosoted pole. The surface had become partially or wholly bleached, and almost white. This generally occurred on that portion of the pole subject to the sun's rays; but it was also equally marked upon that side of the pole exposed to prevailing winds and wet weather. It would therefore seem as if the bleaching was the result both of the influence of the sun and of the weather; in fact that the creosote disappeared from the surface of the pole under the influence of the sun and of wet. If telegraph poles creosoted many years back were examined, as a rule the surface of those poles would be found covered with a

pitchy compound, and that mainly on the side of the pole exposed to the sun. There was no washing out from the weather. This he thought was easy of explanation. The warm atmosphere would always exercise an extractive influence upon any oil injected into wood or other like substance; its tendency would be to bring it to the surface, where the lighter portions would be evaporated, and the heavier portions congealed. Creosote no doubt was a strong antiseptic, but where timber when felled was decayed, it could not give fresh life to the decayed portion. Timber, if properly seasoned, would last many years if not exposed to the vicissitudes of wind and weather, as in the instance of many articles of furniture made from the very same wood from which telegraph poles and railway sleepers were obtained, and which seemingly never decayed indoors. It was here that the creosote process enabled an equally long life to be obtained for it when employed out of doors, and he imagined that the heavier oils played a much higher part in

procuring this immunity from decay than the creosote oil, inasmuch as it was to these heavier oils that the exclusion of moisture from the timber was due. A telegraph pole, or a railway sleeper, free from disease, if properly seasoned, and encased in such a manner as to prevent moisture getting into its fiber, was practically indestructible from rot or decay. The coating given to it by the injection of these heavier oils into the fiber to a depth of from 1 to 2 inches afforded the timber this coating, excluded moisture, and thereby secured its duration.

Mr. C. De Laune Faunce De Laune remarked that the author had attempted to prove that only a very small quantity of carbolic acid was necessary in creosote for the preservation of wood. He approached the subject with diffidence, as he lay claim to no scientific knowledge, merely discussing it from the purely practical side; and because he had been instrumental in extending the use of creosote among landowners and farmers. The author referred to his having used creo-

sote too hot, and thereby having damaged the wood, much in the same way as if he had taken a warm bath too hot. He certainly stated to the author that he had used a material called creosote which contained a very small percentage of carbolic acid, and that the wood had failed to be satisfactorily impregnated with it in an open tank, even when submitted to a great heat; but he scarcely anticipated that he would infer that it was his general custom to use extreme heat, as he only wished it to be understood that even under such conditions the creosote did not perfectly penetrate into the wood. The process of injection, in the case of telegraph poles, might preserve them to an indefinite period, but such a course was frequently impracticable to the former, and in the case of hop-poles impossible; wherefore an open tank was indispensable. For the last twenty years he had used creosoted wood, and the process had always been performed in an open tank. The wood was first cut to the required shape, and

then immersed in the creosote which had previously been liquefied and warmed by a furnace built underneath the tank. No thermometer had ever been used to regulate the heat, and the only precaution taken was to prevent the creosote from boiling over, though it was sufficiently heated to make a few bubbles appear on the surface. Wood of all kinds had been used, and no difficulty in applying the creosote was at first experienced, but he believed that the creosote had gradually been becoming worse and worse, and so he submitted it to Dr. Voeckler for analysis, and got the following reply: "Your creosote has a specific gravity of 1.103, and on being subjected to distillation yields only 61 per cent. of volatile oils, of which 4 per cent. are carbolic acid." My experience in creosoting timber, small as it is when compared with that of public companies, is large for a private individual, as I have at this time 46½ miles of fences where creosoted wood is used; and whereas the system, when employed some years

ago, was satisfactory, the present results are as much the contrary. The pieces of creosoted wood exhibited by Mr. Carruthers were creosoted by me in 1866, and, as was pointed out by him, are perfect in their preservation. Unfortunately I have no analysis of the creosote then used, for such an analysis would prove that a material of the same constituents would be suitable for preserving wood in an open tank. It was obvious, therefore, that a creosote was formerly used that could and did preserve inferior wood in an open tank perfectly, and which could be used so easily that no particular precautions as to the dryness of the wood were necessary, and it was in the hope of ascertaining the component parts of the creosote which he once used with such admirable results, that he ventured on these remarks; for the creosote that he formerly used for preserving wood was as valuable as that which he was now using was useless and worthless, and all he asked of manufacturers was to give him material like what he had before.

Mr. W. Lawford wished to inquire how it was that, in the face of such undoubted proofs of the value of the creosoting process, some of the large railway companies, and notably the Midland, had given up creosoting their sleepers? He considered it the duty of every one who used timber largely to adopt either this or some other antiseptic treatment, since large encroachments were annually made upon the timber-growing districts of the world, without an adequate supply of timber-producing trees being planted for the use of posterity.

Mr. C. Lowe, in reference to the constituents of the creosotes employed for "pickling" or preserving timber, was disposed to attribute to the tar acids only a very small amount of the effective results obtained by the application of the creosote, for the following reasons:

1. Carbolic and cresylic acids were both completely volatile even at an average summer temperature in England, and in hot climates could not long re-

main present (except as traces) in any timber to which they had been applied.

2. Both these acids were readily soluble in water, and would consequently be rapidly removed from the timber in case the latter, previously saturated with them, was subjected to the action of water in motion. He regarded the action of coal-tar creosote in preserving timber as presenting a two-fold character; first, a mechanical action, by which the wood was rendered waterproof from the filling up of the cellular tissue with matter insoluble in water; second, a chemical or antiseptic action, due chiefly to the presence of the tar acids. These tar acids were roughly divisible into the readily volatile acids soluble in water (carbolic and cresylic), and the heavy, almost non-volatile, acids insoluble in water. The latter class had not been thoroughly studied, but it was known to be powerfully antiseptic, and anti-parasitic. He therefore considered the creosote best adapted for the "pickling" of

timber to be a creosote containing sufficient solid hydrocarbon, such as naphthaline, to be solid at a temperature slightly above the average climatic or other temperature to which the timber was to be ultimately exposed; at the same time, to prevent the attacks of parasitic insects, etc., the heavy tar acids should be present. No reliance should be placed on carbolic and cresylic acids for pickling timber, seeing they were so readily removed by the action of water and climatic heat. It was well known that their albuminous combinations were readily broken up by simple washing with water; as germicides and antiseptics, when retained *in situ*, these acids were invaluable for surgical use and disinfection, and to these purposes they should be relegated.

Mr. T. E. M. Marsh exhibited specimens of timber used by the late Mr. Brunel in 1839. These were fair samples of the bulk of the timber of the ribs of the skew bridge over the River Avon, at the Bath station on the Great West-

ern Railway. The timber was cut from Memel balk, and was kyanized. It was quite sound after forty years' service. The kyanizing process had been employed extensively by the late Mr. Brunel in the early works of the Great Western Railway. The permanent-way timbers were thus prepared, and gave excellent results as to preservation from decay, as was shown by specimens cut from various parts of the line, between London and Bristol, after having been laid from fifteen to twenty years. Mr. Marsh had gained much experience in the preparation and uses of creosoted timber, both while acting for Mr. Brunel, and subsequently up to the present time. In the early days of the process, the tar from which creosote was prepared was not subjected to the extraction of so many chemical ingredients as was now the case, and the naphthaline, or salt precipitated was comparatively small, and considered of little value. No difficulty was then experienced in getting a good admixture of light and heavy oil in

a fluid state, of satisfactory color, consistency and taste, and complying with the rough and ready tests adopted. Mr. Brunel adopted the process extensively from its early introduction by Mr. Bethell, in bridges and permanent way, and much of those timbers and structures remained in use at the present day. It was, however, soon discovered that it was of great importance the timber should be well seasoned and dry, and that it was worse than useless to creosote unseasoned, damp or wet timber. Some alarming cases of internal decay had been discovered, attributable to these causes. Of late years, on account of the greater demands on the timber merchants, and for other reasons, the preparation of creosoted timber had not always had such careful consideration. The processes were often carried on, not only not under cover, but water in variable quantities was generally found in the tanks from which the oil was pumped into the pressure-cylinders, and solid salts and a mixture of mud and

the residuum and drainage of objectionable matter from the timber of preceding charges, accumulated in the tanks and returned again, to the detriment of subsequent charges. It not unfrequently happened that timber coming from the pressure-cylinders might be found with some portions presenting no trace whatever of creosote even on the surface, but showing only signs of the contact of dirty water, when the quantity of creosote injected was supposed to have been 50 gallons to the load. Such facts, Mr. Marsh asserted, were sufficient to account for many reported failures, without reference to the chemical questions as to the relative values of the constituent parts of the oil. Mr. Marsh's instructions to his inspectors for the preparation and pickling of timber, where thorough efficiency was desired, were based on his own personal observations, and were as follows:

"The state of the tanks from which the creosote is being drawn while the pressure progresses, and before any

creosoting is done, must be examined, and if found to contain salty or muddy sediment at the bottom, or water at the top, or the nature of the creosote otherwise bad, its use must be protested against. Samples must be taken by a tube dipped to test the liquid at various depths, particularly the upper and lower portions of about 12 inches of the top, and the same at the bottom. This must be strictly attended to. No steam shall be let into the creosote anywhere. The numerous pipes used for heating, and sometimes hoses and joints, may give the means of mixing in steam during the process, and hence the condensed water, which must not be permitted under any circumstances. Sometimes the appearance of the timber after creosoting will show that water has been in contact with it. The thorough good creosoting must also be checked by a chisel at the sound hearty parts of the timber, and the penetration checked by weighing trial sticks with each charge (these should not be open sappy timbers, and they

should be the least dry rather than those to favor absorption more than the bulk in the same charge). A good percentage, over 50 glallons to the load, must be injected so as to allow for outside drainage when drawn out of the cylinder. In weighing, 50 gallons may be reckoned as 550 lbs. If the timber be not quite satisfactory and perfectly dry, and immediate delivery is urgently wanted, then a considerable extra quantity must be injected, as much as 10 per cent., or further drying, and under cover, must be insisted upon, but in no case must positively wet or damp timber be allowed to go into the pressure-cylinders."

Mr. Benjamin Nickels observed that he was much gratified in noting that the author had drawn special attention to the compound acridine, pointing out, at the same time, its high antiseptic value as a constituent of creosoting materials. It would appear that his impressions had been based on certain marked properties exhibited by this peculiar substance, no-

tably its intense pungency, acridity, and high antiseptic value, also its immunity from loss by evaporation and the solvent action of water. As little beyond a mere reference to the compound had been made, it might be of interest to state what had been done in other directions, and so far as it might corroborate the views advanced by its author. In the year 1882 he was induced to take out a patent for a composition to be used as an insecticide, and for the coating of ships' bottoms and other submerged surfaces, and in which acridine played an important part. He had, during a previous experience, met with many opportunities of observing the painfully irritating action of the heavier tar oils, arising from handling during the treatment and purification of anthracine, due to the presence of acridine, and as an outcome of the observation it had occurred to him that this substance should constitute an effective "antifoul," inasmuch as it would be almost impossible for animal life to remain in contact with it. Experiment in nu-

merous directions fully supported the idea; but the question arose, would the acridine resist the prolonged solvent action of water, and remain effective for a lengthened period, and in the thin coating of any composition that could be applied as a paint to a ships' side? Opinion varied considerably as to ultimate success when attempted on a practical scale, although laboratory trials had shown that such composition was unacted upon in still water. The first experiment of any importance was made on a small iron barque (the "Cordova") which sailed from London for the Falkland Islands about the end of January, 1882, returning at the end of October, after an absence of nine months, during which her hull had been constantly submerged. Previous to sailing, portions of her plates towards the lower part of the vessel, and where subjected to the greatest wash, had been coated in the ordinary way of applying a ship's paint with acridine composition, prepared in conformity with the patent referred to. He was present

on her return to England, and upon the vessel being docked for repainting and repair, he made a close inspection of the portion that had been originally coated with the composition. He found that the paint had remained intact, presenting a smooth and unbroken surface; it had adhered most tenaciously to the iron plates, completely protecting them from the action of the sea. There was no adhesion of barnacle or weed, and the evidence of contained acridine was very manifest on applying the tongue to portions of the composition scraped from the side of the vessel. Subsequent examination showed that there had been little or no loss of acridine, and that the prolonged and beating action of swiftly-running and boisterous seas had failed in removing or washing out the acridine originally incorporated in the paint applied. Since the date of this experiment many others had been made, and were still on hand, with vessels on long sea-voyages, and, as far as he was enabled

to state, the results obtained had been of a satisfactory character.

It would be difficult, perhaps, to cite more complete illustrations of the indifference of a substance to severe water action; and the author might, he thought, rest well assured that his statements concerning this singular tar product were in nowise overrated or exaggerated. As regarded the antiseptic character of acridine, he might mention that it was of high value, extremely small quantities being sufficient to arrest the change in many organic substances prone to rapid decomposition.

Mr. Martin F. Roberts wished to direct attention to a point which had influenced engineers in their preference for the so-called "Country oil," viz., that of economy. Engineers would be aware that in drawing up specifications it was usual to stipulate for a certain quantity of creosote to be injected into a cubic foot of timber, usually 6, 8 or 10 lbs., the contractor's price for creosoting being regulated according to the quantity

specified; and it thus became necessary for engineers to consider whether, say 8 lbs. per cubic foot of the thick, heavy, London creosote penetrated as far into the timber as 8 lbs. of the thinner country oils. He was sure all engineers would agree that it would not; and from his own experience he was able to say that, with telegraph poles, in many places where 8 lbs. of London creosote per cubic foot had been injected, it had not penetrated more than half through the sapwood, whereas a similar quantity of country oil would have penetrated completely to the heartwood, although, of course, the country oil would not leave as large a deposit of solid substances in the pores of the timber. It was, therefore, desirable to consider whether it was better to have the sapwood completely injected with thin oil at a certain price, or the outer portion only injected with thick oil at the same cost, and his experience led him to prefer the complete injection by the thin oil. His ground for arriving at this conclusion was that, although he

had met with many samples of creosoted timber in which a portion of the sapwood had decayed where the creosote had not penetrated, he had never met with a piece of timber having decayed where the creosote had penetrated, except in one instance in a Government telegraph pole, referred to in the discussion; and even in this case he thought it well to ask if the decay had taken place before or after creosoting. Engineers acquainted with red fir timber would remember that what was called a "foxey pole" was occasionally found, in which, although the outer portion or all of the sapwood might be quite sound, some of the inner portion of the pole had decayed before felling; and it was often a difficult matter, even for an experienced inspector, to detect such a pole. It would easily be conceived that in such a case the decay might be, and often was, attributed to a defective quality of creosote having been used, instead of to the fact that a portion of the pole was rotten when treated.

The remarks made by the author un-

der the heading of "The Conflicting Theories of Putrefaction," in which he spoke of the "gaping orifice of a crack produced by the sun in a piece of timber," would appear to specially point to the necessity for the use of a thin, penetrating oil, as timber would crack after long exposure in the sun, even if it had been creosoted with the thickest London oil; and in these cases the oil which had penetrated the deepest would be more effective, as it was the most likely to have genetrated beyond the depths of the crack. If it were the practice to completely saturate the entire mass of timber with creosote, and if it were found possible to do so in all cases, there would then be no objection to the use of London oils; but as the question of cost had to be considered, and the smallest quantity of creosote per cubic foot which was found to answer the purpose was therefore specified for, the thinner country creosote was preferred, owing to its greater penetration, weight for weight. In Mr. Coisne's experiment with shavings, the

conditions were so totally different to those met with in ordinary practice, that too much reliance should not be placed in them. It was obviously an easy matter to completely saturate shavings either with thick or thin creosote, but with telegraph poles and railway timber the creosote never penetrated completely through the timber, and it could not be contended that the exclusion of germs alone prevented putrefaction, as, if so, a coating of tar would prevent decay. What was necessary was that the germs of decay in the timber should also be destroyed, and this could only be accomplished by bringing all that portion of the timber more liable to decay—viz., the sapwood—under the influence of a creosote of considerable penetrating power. If evidence in support of this assertion were needful, it would only be necessary to refer to the fact that engineers strictly barred the use of whitewood timber for telegraph poles and other purposes, owing to its being found impossible in practice to inject creosote into whitewood to a greater

depth than $\frac{1}{2}$ or $\frac{3}{4}$ of an inch from the surface, and whitewood timber so prepared, either with London or country creosote, was found to decay rapidly. It would appear that the best system of creosoting would consist in first injecting the timber with thin "country oil," then running the thin oil off and filling the cylinder with London creosote, which, being forced in by increased pressure, would drive the thinner oil further into the timber, and the thicker creosote would hermetically seal the outer pores of the timber. Failing this process, owing to its increasing the cost, it would appear advisable to use thin creosote, and if it was considered that thin oil did not sufficiently fill the outer pores of the timber, the process, at a trifling cost, could be supplemented by giving the timber a coat of hot tar.

Mr. Greville Williams stated that he regarded the paper as the most valuable and exhaustive contribution yet made to the literature of the subject. He agreed with Dr. Meymott Tidy and the author in

considering that the value of the carbolic acid in creosote oils had been overrated. He believed that an oil from which the carbolic acid had been removed would sterilize wood, if thoroughly impregnated with it, partly by virtue of the organic alkaloids present, and partly by the protective influence of the heavier oils themselves. He had satisfied himself by careful experiments that the alkaloids exercised a potent influence in preventing the development of bacteria, mould, and microscopic fungi in vegetable infusions. He thought, moreover, that where wood had to be exposed to the action of sea-water, it would be advantageous to use a creosote containing a high percentage of the alkaloids; this could easily be attained by well-known methods. Although the minute quantities of carbolic acid remaining in old creosoted timbers were too small to account for their preservation, he considered it right to say that, by a sufficiently delicate method of manipulation, he had rarely failed in getting evidence of its presence even thirty years after the

wood had been creosoted. He found traces of it in eleven out of fourteen specimens which had been creosoted from twenty-five to thirty-two years before. The organic alkaloids, however, which remained, were sufficient to allow quantitative estimation. He thought that no chemist, who had examined very old sleepers for carbolic acid, could come to any other conclusion than that the traces remaining were insufficient for their protection. A point, moreover, of great importance for the proper comprehension of the subject, was involved in this almost entire disappearance of the carbolic acid. If the coagulation of the albumen by the carbolic acid were the cause of the preservation of the timber, how was it that this acid almost entirely disappeared? The instability of the compound, of albumen with carbolic acid, was well known to those chemists who had minutely examined it; nothing more conclusively proved this instability than the disappearance of the carbolic acid. With regard to the naphthaline, he thought it significant that

it was only absent from two of the sleepers he had examined. There could, he considered, be no question that naphthaline, although perhaps feeble as a germicide, properly so called, was very valuable as a sterilizer; it was insoluble in water, and once in the wood, clung to it tenaciously. He was also most decidedly in favor of the removal of all restrictions as to maximum boiling-point, and considered that, if the oils were fluid at the temperature of injection (say 100° to 120° Fahrenheit), that was all that was needful. On the whole question, he found himself able to thoroughly indorse the conclusions of the author and Dr. Tidy, and he considered that specifications which excluded the use of London oils were framed under a misapprehension of the true nature of the condition requisite to afford a good creosote.

Mr. Boulton had been obliged to be very brief in his verbal reply at the close of the discussion, and as some of the points then raised involved matters of considerable detail, which had also been

alluded to in the correspondence, he thought that unnecessary repetition would be avoided if he were to connect his replies to both series of communications in a continuous form. He was gratified at the valuable support which his main propositions had received.

The remarks made by Dr. Tidy, and the views expressed by that gentleman in his recent report to the Gaslight and Coke Co. were in principle in accordance with the views expressed in the paper. The author, however, believed with Dr. Armstrong that Dr. Tidy, who had been somewhat conservative on the subject of tar acids, would be led by the logic of facts to accept a much lower proportion than 8 per cent. The "London creosotes" as they came from the still, honest creosotes which had done excellent work, and which constituted probably about one half of the total supply of this kingdom, did not contain so large a percentage. Some misapprehension still existed on this subject, which the statement of a few facts might remove. In July, 1863,

the author sent to Dr. Letheby a sample of the usual London creosotes, which he was then largely using. Dr. Letheby found it contained only 4.37 per cent. of tar acids. Later on, and during one period of seven years especially, nearly the whole of the tar of the great London Gas Companies, as well as tar from other sources, was contracted for and distilled by the author's firm. The quantity was probably larger than had ever been treated up to that time by any one firm or corporation, and it therefore formed a sufficiently broad basis for estimation. He would give the quantities during three consecutive years—

1877	Gallons of tar distilled....	14,735,404
1878	" " "	15,839,819
1879	" " "	12,690,029

or an average of between fourteen and fourteen and a half million of gallons per annum. He had found, as stated in the paper, that the heavy oils distilled from this mass of tar contained on an average from 4 to 7 per cent. of total tar acids. More recent experiments which he had

made upon a large number of London tars—one series in May, 1882, another in August, 1882, and a third since this paper had been read—gave similar results. Latterly, the largest of the English gas companies, the Gaslight and Coke Co., had erected works at Beckton, at which they distilled their own tar. It had been assumed that the list of analyses appended to Dr. Tidy's printed report represented the percentage of tar acids which the London creosotes in their natural condition contained. This, however, was not the case. The samples analyzed by Dr. Tidy contained from 8.2 to 10.2 per cent. of tar acids, but they had been specially treated to "meet the market," created by the modern type of specification by removing from the creosote some of its least volatile parts, those parts containing little or none of the volatile tar acids. The Gaslight Co.'s creosotes as they came from the still contained on an average 6 per cent. of total tar acids by the ordinary caustic alkali test. The author had been enabled to clear up this

matter, of which experts would readily detect the importance, owing to the courtesy of the Board and Secretary of the Gaslight and Coke Co.

He agreed with Dr. Armstrong in the importance of M. Pasteur's experiment upon sawdust, which was recorded in the Comptes Rendus of the Académie des Sciences for 1863. It is remarkable as an early demonstration of the application of the germ theory to the phenomena accompanying the decay of woody fiber. Dr. Armstrong had alluded to the distinction between wood creosote and tar creosote. Both contained tar acids, some of which might be identical, or if not identical, isomeric. But tar creosote, if it could be so called, was a complex body; some of the tar acids it contained differed essentially from either carbolic or cresylic acid, being less volatile, and less soluble in water than either phenol or cresol. There is evidently room for much further investigation in this connection; also for a more complete comparison between the

"tar acids of the coal-tar oils and similar bodies contained in other oils."

In relation to the remarks of Mr. W. Foster, the author must express the hope that that gentleman would continue the very interesting researches of which he had so recently given an account to the Institution in his valuable paper on "The Composition of Coal." Authentic Tables as to the varying products derived from different kinds of coal, and at different temperatures, were becoming matters of the first necessity in various branches of industry. Mr. Foster had referred to the experiment of Pettigrew, alluded to in the paper. Pettigrew had removed the embalming material from the heart of the mummy by steeping it in alcohol; after which, upon exposure to the atmosphere, putrefaction took place. What the author desired to point out was that the previous immunity from decay had not been the result of any chemical combination between the antiseptic and the tissue.

A jarring note had been struck by Mr.

Bamber, who had represented "the whole secret of the paper" to consist in "the author's idea..... that nothing should be left in the creosote which it would pay him better to take out;" an object foreign to the declared aim and intention of the paper. The author had not approached the subject from the commercial point of view—a fact which the President had so gracefully recognized. It might, however, be opportune to state that he was not at present commercially interested in any manufacture which caused carbolic acid to be "taken out" of the creosote oils, although he was largely interested in the success of prepared timber as an engineering material, and therefore in the choice of the best antiseptics for that purpose, whether obtained from the creosote oils or from other sources. Mr. Bamber's figures as to the comparative commercial values of creosote oils and carbolic acid, recalled to memory the well-known comparison between the value per ton of iron ore and of steel watch springs. The manufacture of pure carbolic acid was

a long and costly process, of which the first cost of the crude material formed an altogether insignificant item. Nor was so low a price as 2*d.* per gallon for creosote either "proverbial" or usual. But it would be found in the long run that the consumer had to pay the commercial value for everything which the creosote contained, and it was therefore best to discuss upon scientific and practical grounds the substances which the engineer should require it to contain. It was one of the main objects of the paper openly to point out by diagrams and detailed descriptions the principal substances contained in the coal-tar oils, to draw attention to their properties, and to state their uses for various manufactures, so that for the purposes of timber-preserving, engineers might be in a position to "prove all things, hold fast that which is good." Mr. Bamber was mistaken as to facts in his allusion to Dr. Letheby's specification, and that of Dr. Tidy. Dr. Letheby's specification, drawn up under instructions from Mr. Meadows Rendel, M. Inst. C.E.,

in 1865, for the use of the East Indian Railway Company, stipulated that the creosote was to yield to a solution of caustic potash, not less than 5 per cent. of crude carbolic, and other tar acids. Dr. Letheby never increased that quantity. Dr. Tidy had increased, and not as Mr. Bamber supposed, diminished the percentage of tar acids mentioned by Dr. Letheby.

Mr. Bamber complained that no facts or data had been given respecting Dr. Tidy's experiments on naphthaline. But the paper contained a reference to a printed report of Dr. Tidy, deposited in the library of the Institution, wherein was a full account of these experiments. They were also recorded and approved of by Dr. Lunge, of Zurich, in his learned work upon "The Distillation of Coal Tar." Amongst other authorities who after investigation differed from Mr. Bamber in admitting naphthaline as an ingredient in the timber-preserving oils, were the late Mr. Bethell, Mr. Burt, Prof. Sir Frederick Abel, Mr. Forestier, for the French Government, Mr. Coisne, for the Belgian Gov-

ernment, &c. Mr. Bamber had once stated to an eminent engineer, in a report upon a creosote highly charged with naphthaline, that timber impregnated with such an oil would, "within a very short time of the timber being in India, lose 5 lbs. out of every 10 lbs. put into the timber here merely by escape of naphthaline." Dr. Tidy's experiments with timber injected wholly with naphthaline, and subjected to a temperature of 130° Fahrenheit, proved that these apprehensions were unfounded. But it was now related by Mr. Bamber that in his own experiment a piece of wood impregnated with a creosote of the type which he preferred, and containing 20 per cent. of tar acids, lost in four weeks 42.33 per cent. of the oil taken up. Mr. Bamber's record of his own experiment was very instructive. He tried two kinds of creosote against each other. One, which might be called specimen A, was "full of naphthaline," but the percentage of that body was not stated. It contained 10 per cent. of tar acids. Specific gravity not named. With this

oil a piece of deal 3 inches by 3 inches by 8 inches was impregnated. The other, which might be called specimen B, was a "country oil," specific gravity 1.045, containing 20 per cent. of tar acids. With this oil a piece of deal 3 inches by 3 inches by 6 inches was impregnated. Specimen A was alluded to as "Mr. Boulton's own oil" and "the author's London creosote;" but to these appellations he demurred, as he never used a 10 per cent. creosote unless required to do so by specification, and the London oils did not in their natural state contain 10 per cent. of tar acids. Therefore A, although it might come from his works, would be a mixture of London and Country oils. But, although in the author's judgment too volatile, yet the 10 per cent. specimen would be less volatile than the 20 per cent. Therefore, the author preferred A to B. Where a large issue was staked upon a single minute experiment, accuracy of result should be ensured by the most minute precautions. It was not explained why the two pieces of deal were

not cut to the same size, a circumstance which affected the conditions both of absorption and of evaporation. Nor were the specific gravities of the two pieces of wood stated. Of two pieces cut from the same log, one piece of wood would frequently absorb, under the same conditions, a very much larger quantity of fluid than the other. However, the results as stated might be calculated as follows:—

A. Piece of wood, capacity 72 cubic inches, absorbed 1,020 grains of creosote =3.49 lbs. per cubic foot.

B. Piece of wood, capacity 54 cubic inches, absorbed 1,785 grains of creosote =8.17 lbs. per cubic foot.

But no pressure was used, and engineers would recognize that the experiment failed to reproduce the conditions of the ordinary creosoting cylinder. It was well known that without pressure, light oils penetrated timber more easily than heavy oils. In like manner the adulterating substance, bone oil, penetrated more readily than creosote; solutions of metallic salts more readily still; and water

more readily than all. But it was "light come, light go;" those which penetrated most readily were generally the least permanent. The main object of the engineer was not to select the fluid which gave the contractor the least trouble to inject. He desired to select the antiseptic which was likely to be the most efficacious and the most permanent, and he required the contractor to provide efficient apparatus, and to inject under pressure a stipulated quantity by weight. Sleepers and large logs of timber were injected without difficulty with creosotes of a heavier type than either of Mr. Bamber's samples, and to the extent of 10 lbs. and 12 lbs. per cubic foot. Small pieces of wood could be easily gorged with creosotes. The author had recently injected some fir paving blocks 6 inches by 6 inches by 3 inches, with 22 lbs. per cubic foot of ordinary heavy London creosote, containing about 5 per cent. of tar acids. Mr. Bamber exposed his specimens to evaporation on a mantelshelf at a temperature never above 70° Fahren-

heit, and generally between 40° Fahrenheit and 50° Fahrenheit. In four months A had lost 47.75 per cent., and B had lost 42.33 per cent. of the creosote put in. If this could be taken as a normal result, engineers would hesitate as to employing either type of creosote. No doubt both were too volatile. But it should also be borne in mind that the injection was imperfect; to use Mr. Bamber's "expression, it was only "skin deep." As regarded the comparative evaporation of the two specimens, however, the result was extremely valuable. It is well-known that the evaporation of fluids (except when in a state of ebullition) was in proportion to the surface exposed, and not to the bulk of the fluid. This point Mr. Bamber appeared to have forgotten; he had exposed A, the creosote he disliked, to a wider evaporating surface than that to which he had exposed B, the creosote which he preferred. The position on the mantelshelf in which the pieces of wood were placed was not stated. But supposing them to have been suspended, say

by a thread, so that all the surfaces were exposed to evaporation equally, the results might thus be calculated:

A. Piece of wood, the sum of whose superfices was 114 square inches, lost 487 grains=4.29 grains per square inch of exposed surface.

B. Piece of wood, the sum of whose superfices was 90 square inches, lost 575 grains=6.39 grains per square inch of exposed surface.

If, however, each piece of wood had been placed with one of its sides in contact with the mantelshelf, so that one surface was protected from evaporation, the calculation became slightly modified, so that A would have lost 5.41 grains, and B 7.98 grains per square inch exposed. If the specimens had been placed on end, then A showed a loss of 4.64 grains and B of 7.09 grains per square inch. Mr. Bamber had therefore been mistaken as to the comparative volatilities of naphthaline and the tar acids, as proved by his own experiment. B, the creosote with 20 per cent. of tar acids,

had lost about 50 per cent. more than A, the creosote with 10 per cent. of tar acids and "full of naphthaline." Had it been otherwise, every chemical treatise describing the properties of these bodies, would have to be re-written. The statement that part of the loss of specimen B was due to the fact that some of the oil drained out of it, which it was said "was not fair" to that specimen, gave rise to the rejoinder, was it quite fair to a timber-preserving process that a type of antiseptic should be recommended which "drained out" with so little provocation? This part of the discussion might almost appear trivial, were it not for the fact, confirmed by many special instances in the author's experience, that whenever these light oils had been used exclusively, whether for marine work or for railways, complaints invariably arrived, sooner or later. Oils of so light and volatile a nature lost a large portion of their bulk, which evaporated or drained out in the creosoting yard, on the export ship, and on the permanent way in India and else-

where. An experiment, easy to carry out without any laboratory apparatus, may be tried by any one interested in this subject. Take three saucers or shallow dishes; place in one saucer 200 grains of pure carbolic acid (crystallized), in the second 200 grains of pure cresylic acid, and in the third 200 grains of pure naphthaline. Expose them side by side in any room, and at any ordinary temperature. The crystals of carbolic acid would liquefy in a few minutes, owing to the avidity with which that body absorbed moisture from the atmosphere. In a few weeks' time (varying with the temperature) the carbolic acid would have entirely disappeared by evaporation. By that time the cresylic acid would have lost about half its bulk. When the whole of the cresylic acid had also evaporated. The naphthaline in considerable bulk, at least one-half of the original weight would still remain, an easy victor in the trial of endurance.* The evaporation was

* This experiment was carried out on a mantelshelf at the Institution of Civil Engineers in August, 1884, with the result indicated by Mr. Boulton.

greatly retarded by the incorporation of those bodies with the less volatile oils, and by their being driven into the cells of the timber. But the evaporation must necessarily take place in proportion to the respective and recognized volatilities.

Allusion had been made by Mr. Bamber to "charred oil," and he presumed that it was a residue of anthracene manufacture. The author in the course of his experience had never met with "charred creosote," except indeed as a result of over-heating in a laboratory experiment; nor was he acquainted with any ordinary process of manufacture by which it could be produced. Creosote oils were distillates; whatever the heat in the still, the residuum might become carbonized, but not the substances which came over in the form of vapor. Anthracene or paranaphthaline had been denounced by the creosote specifications of the theorists at a time when it was considered worthless for any purpose; it was taken out of the creosote by every tar-distiller in England, whether in London or country, and was

now of value for the manufacture of alizarine. The removal was effected by a simple process of filtration; the resulting oils were the green oils, the best part of creosote for timber-preserving, fluent and rich in alkaloids. How could they become "charred oils?"

In the illustration, drawn from a fire-engine, it was forgotten that a fire might break out a second time, and that if a fresh supply of water were not available, the building would be consumed. Carbolic acid evaporated rapidly from timber, and it had been proved that it left no permanent effects behind. When the sleeper was placed in the permanent way the supply of the antiseptic could not be renewed, and the timber would rot if more stable antiseptics were not present in the shape of the heavier oils.

As regarded naphthaline colors Mr. Bamber was also mistaken. They were very successful as a manufacture, and their use was largely increasing. He accused the author of "condemning country oils," and of saying that they

"were not good for creosoting timber." In the paper the exact contrary was stated. The author advocated the use of both London and country oils, and he habitually used large quantities of both. What he condemned was the use of oils, whether London or country, which were so manipulated as to contain a large proportion of volatile substances at the expense of the more durable, and therefore for this purpose more valuable antiseptics. Were Mr. Bamber's theories carried into practice, about one-half of the creosote manufactured in England, the enormous bulk of the "London oils," would be excluded from use by the timber-preserver. Nevertheless they were precisely the creosotes which had given the most unmistakably good results, whether, as in the case of the early Indian sleepers, and of the sleepers of the Chemin de Fer de l'Ouest, the percentage of tar-acids had been proved to be small, or whether, as was the practice of the Belgian Government, the tar-acids had been altogeth-

er and avowedly struck out of the specification.

In reply to Prof. Voelcker, he desired to state that he had purposely abstained from connecting the names of administrative bodies with the questions of controversy. He was not aware of any specification officially issued by the War Office which bore on this subject; but it was known that the distinguished chemist of that department had been consulted by various administrations, who could have had no other object in view than to obtain the best engineering material. The views of Sir Frederick Abel on all the most important points of a creosote specification were substantially the same as those of Dr. Tidy and of the author. And what the author considered to be the most important points were, 1st, that the presence in considerable volume of the heavier and least volatile distillates, *i. e.*, those distilling at or above 600° Fahrenheit, must not merely be tolerated but insisted upon. That naphthaline, and the other usual semi-solid constituents,

should be admitted, provided they were completely fluid at the temperature to which the creosote was raised when injected into the wood. It was known that these views had not been adopted by the Crown agents for the colonies, but he hoped that this discussion might be the means of clearing away many misconceptions. Respecting the point which he considered subsidiary to the other two, although not unimportant, viz., the percentage of tar acids, Sir Frederick Abel, as well as Dr. Tidy, had recently recommended a reduction, and the last word had not been said on this question. Prof. Voelcker was mistaken in thinking that Dr. Tidy had recommended 8 per cent. of carbolic acid. The 8 per cent. was of total tar acids, including carbolic, cresylic, and all other tar acids which could be removed by a specified solution of caustic soda. Dr. Tidy, in his report to the Gaslight Co., mentioned his reasons for not stipulating for a fixed quantity of carbolic acid. Whenever any stated quantity of this body had been mentioned in specifi-

cations by English engineers, it had been fixed at one-half of the total tar acids. Hence the quantity had varied from 2½ per cent. to 5 per cent., the latter being the largest quantity of crude carbolic acid which the author had ever known to be required by any specification issued in this country. He might be permitted to express his satisfaction that Dr. Voelcker had recently joined the ranks of investigators into the properties of creosote oils, but he was sure that so distinguished a chemist would be the last to depreciate the experiments and experience of the numerous chemists and practical men who had placed the results of their labors on record. It could surely have only been by some misconception that Dr. Voelcker recommended an entirely new departure by asking for 10 per cent of carbolic acid in creosotes used for young timber or sap-wood, although he admitted the probable superiority of the heavier oils for timber intended for railway sleepers and other engineering purposes. Dr. Voelcker had not produced the results of any orig-

inal experiments in support of his views. The typical experiments which he asked for had been tried and recorded; they proved that carbolic acid and the lighter tar acids were not reliable as durable antiseptics for timber. Engineers were familiar with the preparation of young wood and sap-wood as well as with that of older timber. The same creosotes were always used for both, and with complete success. It had been clearly established that the heavy oils preserved sapwood from decay. It would be remembered by many members of the Institution that the late Mr. Bethell had even advocated the use of young wood in preference to older timber, because the sapwood absorbed the creosote so readily, and that Mr. (now Sir John) Hawkshaw had combated this idea, not from any doubt of the preservation of young wood, but upon the ground that the engineer must choose for many purposes the kind of timber best adapted for resisting impact or heavy strains. Amongst the numerous successful specimens of creosoted

wood which had been exhibited at the Institution during the discussion, and which had been taken from various railways after periods of endurance varying from sixteen to thirty-two years, nothing was more striking than the perfect preservation of the sap-wood, although careful analysis had shown that the heavy oils, and not the tar acids, were the enduring agents of preservation. The allusion of Dr. Voelcker to telegraph poles had elicited much practical information. Nothing could be more conclusive than the evidence of Mr. Preece as to the behavior of the young timber, surrounded by its girdle of sap-wood, which was used for telegraph poles in this country. The author had been responsible for the creosoting of a large portion of the poles alluded to by Mr. Preece; these had as a rule been prepared with the usual London oils. But it was only right that he should state another circumstance. He believed that the success of the poles, creosoted for the Post-office Telegraph Department, was largely influenced by the

care taken by that department in the seasoning of the timber. The date of delivery of the poles, landed and stacked at the creosoting yard, was a matter of contract, but there was no fixed date for the creosoting. On the contrary, the engineer did not allow them to be creosoted until he pronounced them to be dry, and ready for the process. Sixteen years ago, at a meeting of the Institution, he had urgently recommended the adoption of some such method for ensuring the proper seasoning of timber. The very interesting and satisfactory evidence of Mr. Bouissou, the Engineer of the West of France Railways, confirmed the experience of Mr. Preece, both as to the satisfactory results of creosoting, and also as to the great importance of seasoning before creosoting; the precautions adopted for the latter purpose by the French company being substantially the same as those of the English administration. With reference to the preparation of telegraph poles, a very valuable paper had been contributed by Mr. William Langdon,

M. Inst. C. E., to the Society of Telegraph Engineers, on the 25th of March, 1874. Mr. Langdon had also contributed to this discussion, and had confirmed by his experience many of the views entertained by the author. With regard, therefore, to the observations of Dr. Voelcker as to green or unseasoned timber, the author would add the results of his own long and varied experience in this and other countries, by saying that the attempt should never be made to inject creosote, or any other oily substance, without previously, or at the time of the operation, expelling watery moisture. Timber should not be felled whilst the sap was in it.

As regarded the effects of living organisms, and the introduction of their spores through cracks in the wood, the views of Mr. Carruthers entirely agreed with those expressed by the anthor. But what was the remedy? The botanical aspect of the question had not been lost sight of, from the days when Dean Buckland and others discussed at this Institution the question of timber preparation from that important

standpoint, and it had not been overlooked in the modern systems of injection. Exogenous trees, whose annual growth took place by the formation of concentric layers of vascular tissue added externally, furnished the timber with which engineers had almost exclusively to deal. The softer and younger wood, containing the greatest portion of albumen, was on the outside; it was more liable to decay than the harder portions. It was the chief merit of the system of injecting under pressure that it precisely met this difficulty. The softer parts absorbed more of the antiseptic than the rest, the pressure followed the line of least resistance, the antiseptic fluid gorged the sap-wood, and penetrated to all cracks or shakes. There was but little analogy between this method and the application of a surface coating of pitch, as although he recommended by preference 'oils of a heavy character, and containing semi-solids, the whole of these bodies were perfectly liquid at 100° Fahrenheit, the temperature to which they were usually

subjected at the time of injection. On cooling, they solidified, not on the surface merely, but within the pores of the timber, which they sealed up against the incursion of the agents of decay. Mr. Carruthers had referred to the experiments of the celebrated Dr. Koch. The researches of Koch, and of other German scientific investigators, were very damaging to the claims of carbolic acid as a germicide, and as a coagulator of albumen. In his treatise "Ueber Desinfection," Dr. Koch deduced from his careful and laborious experiments minutely described, that the value of carbolic acid was greatly limited as a germicide, and that for the destruction of spores it was altogether useless, being almost without action; but that it could be used to destroy micro-organisms free from spores. This was when used in a watery solution; still stronger was his opinion as to an oily solution. He stated that in solutions of oil or alcohol, carbolic acid did not exhibit the slightest antiseptic action. To this, the remarks of Dr. Sansom had al-

ready pointed. It must be remembered that it was in an oily solution, *i.e.*, dissolved in the tar oils, that carbolic acid was applied to timber. G. Wolffhügel and G. v. Knorre followed up Koch's investigations, and spoke of the inactivity of an oily solution of carbolic acid; of its inferior powers of penetration into porous solids, and of its inferiority in the destruction of fungi. F. Boillat, who followed up the experiments of Koch in the laboratory of Professor Nencki at Bern, found that albumen, when completely coagulated with an excess of carbolic acid, formed no permanent combination therewith. He was able to wash out on a filter the whole of the carbolic acid from the albumen precipitate, after which, upon exposing it to the atmosphere during forty-eight hours, the albumen became putrid. Mr. Carruthers had spoken of the presence of free crystallized carbolic acid in the cells of a small piece of a wooden hurdle. But carbolic acid would not crystallize out of the oils holding it in solution; it could only be ob-

tained in that state of purity by a long and complicated chemical process, and the crystals would immediately liquefy when exposed to the atmosphere. The minute particles seen by Mr. Carruthers were probably naphthaline, or one of the other semi-solids of the higher distillates of coal-tar. The condition of this hurdle corresponded exactly with that of enormous masses of successfully creosoted timber as typified by the samples exposed during this discussion, and the author thought that the final question of Mr. Carruthers had been fully answered by many authorities quoted in the paper.

In reply to Mr. C. de Laune, the author would remark that his paper had a much wider object in view than the mere question of carbolic acid; the presence or absence of that body would not explain Mr. de Laune's difficulty. No honest creosote made from coal-tar, whether "London" or "country" oil, whether with much or little tar acid, contained any ingredient which could injure timber; the only question was, which of those in-

gredients was most efficacious and most durable. The question as to which was the easiest to put into the timber was of much less importance. Some small pieces of hurdles, &c., had been shown during the discussion, and alluded to by Dr. Voelcker, Mr. Carruthers, and Mr. de Laune; Mr. E. A. Cowper had detected the reason why one had succeeded and the other failed. The first had had plenty of creosote put into it; the others but very little. Mr. de Laune had made a detailed statement to the author, which was briefly as followed: That he had been in the habit of preparing different kinds of timber of various densities, and frequently in a wet or unseasoned state by boiling the wood in creosote in open tanks and without a thermometer; and that he did not keep the timber in the tanks more than twelve hours, as a longer operation rendered it brittle—a very significant fact. He said that he had not latterly superintended these operations personally, and that he did not regard the process as a scientific one, but thought

that it could be carried out by odd hands, old men, or boys. A good many years ago, the author had had considerable experience in preparing timber in open tanks with corrosive sublimate, sulphate of copper, and also with creosote. The time for leaving the timber in the tank, to be injected by the metallic salts in watery solution, which penetrated more readily than creosote, was generally calculated at about twenty-four hours for every inch in thickness of the wood. With the creosoting process it was essential that the water in the timber should be first got rid of; the presence of the water prevented the entrance of the creosote oils. Even with the cylinder-process, where the oil was driven in under pressure, engineers insisted upon the timber being dry, and they weighed it before and after the operation, to check the quantity of creosote injected. With the open-tank system more care, and not less care, was necessary than with the superior apparatus. But soft young timber, if properly seasoned and then

subjected to creosote at a moderate heat, could without difficulty be made to imbibe a sufficient quantity of creosote of any kind manufactured in this country. But if the timber was wet, it was not amenable to treatment by creosote in open tanks at a moderate temperature, and if the creosote was raised to a temperature even approaching to its boiling-point, which was about 400° Fahrenheit, it would cause the timber immersed in it to become as brittle as a carrot. Timber should not, under any circumstances, be subjected to a higher temperature than 250° Fahrenheit. It would, therefore, appear that Mr. de Laune's difficulties were to be explained by his methods of operation. He had told the author that he had for many years procured all his creosote from the same works, a small local manufactory, where the tars of the district were distilled. It had been ascertained that the creosotes manufactured at the works in question had not essentially varied in type, whilst even as regarded carbolic acid, if the analysis quoted by

Mr. de Laune was correct, the quantity contained in the sample was considerably above the average, although this was a point to which the author attributed but little importance. He was surprised to find, in the report accompanying the analysis alluded to, a statement to the effect that "good creosote should yield quite 75 per cent. of volatile oils (*sic*) containing 10 to 15 per cent. of crude carbolic acid." No creosotes used for timber-preserving, under any specification, had ever been required to contain more than from 2½ to 5 per cent. of crude carbolic acid. The recommendation of "volatile oils" was a mistake which was obvious to all experts; but it might have a bad effect in encouraging the use of some of the worst adulterants, substances sold as creosote which were not derived from coal tar at all. The report, although issued from the laboratory of the Royal Agricultural Society, was signed for, but not by, Dr. Voelcker. The author had understood that Dr. Voelcker was at the time absent owing to illness; he would

not therefore have alluded to it but for the fact that this report had been brought so prominently into notice by Mr. de Laune, and that extracts from it had been published in an agricultural journal.

The author had used creosoting for farm purposes, for fences, hurdles, and for many years also, for piles and fences for his wharves. He always used for himself the type of creosote he recommended to others, and it had proved invariably successful in his own case.

The author was asked by Mr. Cleminson why he had not alluded to the process of Mr. Blythe. If by Blythe's process was meant the attempt to introduce the creosote oils, or any part of them into timber in the form of vapor, the subject had been fully treated in the paper. For the operations described as having been carried out for the Compagnie des Chemins de Fer de l'Ouest, the apparatus used was supplied by Mr. Blythe. The experiments of Mr. Seidl were described by him as having been carried out by "Blythe's process." Engineers in Eng-

land had recently had an opportunity of witnessing similar experiments at the works of Messrs. Connor, at Millwall. After the dismantling of these works, the author had purchased the greater part of the machinery for the purpose of adapting it to his own processes, so that he had again had an opportunity of studying the question. By slow evaporation, fluids gradually volatilized at temperatures much below their boiling-points. But pressure from their vapors could only be obtained at temperatures exceeding their boiling-points. Thus water gradually evaporated even from a frozen surface, but no tension of its vapor could be produced except at a temperature exceeding its boiling-point, 212° Fahrenheit. The boiling-point of the creosote oils ranged from about 400° to 760° Fahrenheit, that of carbolic acid when separated from these oils being 360° Fahrenheit, and of cresylic acid 390° Fahrenheit. Now, it was well known that timber for the purposes of the engineer was injured and rendered brittle and unsafe at a temperature much ex-

ceeding 250° Fahrenheit. How then could those tar products be introduced under pressure into the timber as vapor, whether accompanied or not by superheated steam, without injuring the timber? Either the temperature must be raised above danger point for the wood, or nothing but the vapor of water would be driven into it. This applied to the first part of the process. Of course, if it was followed up by an injection of the creosote oils in the usual manner, this second part of the process covered the deficiencies of the first operation. The presence of any of the components of the tar-oils could be detected in the timber by chemical tests. When specimens of wood had been produced, which had been prepared by the injection of tar-oil vapors in sufficient quantity to have a practical value in the preservation of timber, and at a temperature not exceeding 250° Fahrenheit, the author would be very glad again to give his best attention to this part of the subject.

He was glad to be able to reply to the

question of Mr. Lawford, with regard to the Midland Railway Company. In 1866, at a meeting of the Institution, Mr. Crossley, the engineer of that company announced that, although he admitted that creosoting stopped decay, he had given up that process from a calculation of economy based on the assumption, that with very heavy traffic like that which prevailed over the lines of his company, the sleepers were worn out by hard work before they had time to decay. The author would suggest that incipient decay of unprepared sleepers often set in at a very early period of their service, especially through cracks and bolt-holes; the fastenings of the chairs thereupon became loosened, and the mechanical destruction of the sleepers hastened. But Mr. Lawford would be glad to hear that the Midland Railway Company had again adopted creosoting; they had had large quantities of sleeper creosoted during the last few years.

In reply to Mr. Roberts, the author had never found any difficulty in com-

pletely saturating the sap-wood with the London oils where the timber had been sufficiently dry. Mr. Coisne's experience with shavings were for the purpose of ascertaining what kind of creosote lasted best, and he effected a complete saturation both with the thin oils and with thick oils. The thinnest oils did not preserve the woody fiber from rotting, even with so good an injection, whilst the heavier oils did. *A fortiori*, the thinner oils would be, by themselves, still more unreliable with the inferior injection carried out in practical operations with timber. It must also be borne in mind that Mr. Coisne did not stop at these experiments, but had confirmed them by twenty years' subsequent treatment of timber on a very large scale, for the Belgian State Railways. The chapter in Mr. Coisne's 1871 pamphlet, upon the choice of creosote oils was a most interesting and practical one.

With reference to the author's process for removing water from the timber at the time of creosoting, the following ex-

periment had been carried out at his works since the paper had been read.

Six square fir-sleeper blocks, each 8 feet 11 inches by 10 inches by 10 inches, saturated with moisture, were cut into 10 inches by 5 inches sleepers. One sleeper, A, from each block was prepared by the new method, the corresponding sleeper, B, from the same block, by the old method, so that in each instance the results with the two halves of the same log could be contrasted. Care was taken to choose blocks having the heart in the center, and with the texture of the two halves as nearly as possible similar.

From the six sleepers, A, water was withdrawn by the new process to the extent, ascertained by weighing the water, of 120 lbs.; yet the sleepers, when withdrawn from the cylinder after the process was completed, weighed 155 lbs. more than when put in, thus showing that they had absorbed 275 lbs. of creosote. As their total cubic contents were 18.57 cubic feet, their average loss of water was 6.45 lbs. per cubic foot; their aver-

age gain of creosote was 14.8 lbs. per cubic foot.

The six sleepers, B, were creosoted by the ordinary process. Being, like the others, very wet, and having no moisture extracted from them, the results of their being weighed before and after creosoting showed an absorption of 116 lbs. of creosote only, or an average of 6.29 lbs. per cubic foot. The separate absorptions of these six sleepers were as followed: 9.04 lbs., 4.52 lbs., 2.9 lbs., 6.13 lbs., 9.36 lbs., and 5.49 lbs. per cubic foot respectively, thus illustrating the uncertain results of creosoting timber when too wet by the ordinary method. They were placed in the cylinder with a charge of ordinary dry sleepers, which took up on the average rather more than 10 lbs. of creosote per cubic foot.

The result with sleepers A was interesting, as it showed that by the new process wet timber could have its moisture at once removed, and a large quantity of creosote injected without difficulty. All twelve sleepers, both A and B, were

afterwards cross-cut at 6 inches, 9 inches, 12 inches, and at 4 feet 6 inches from their ends, the corresponding section of A and B being constrasted and photographed. The sleepers A were found not only to have absorbed a large quantity of creosote, but the creosote was much more evenly distributed than was the case with sleepers B.

Might the author be permitted to sum up the evidence which had been produced during the discussion as to the best class of antiseptics for timber? Both engineers and chemists would probably agree with him that after forty-five years' discussion of this engineering problem the time had gone by for dogmatic assertion, unsupported either by experiment in the laboratory or by recorded experience in engineering works. In the paper he had called the germ theory a severe but salutary test for these antiseptics. As a matter of fact, the subject had received valuable elucidation from the labors and discoveries of a number of eminent men, who had studied the physi-

ology of the bacteria. In the application of the remedies, however, the operations of the timber-preserver diverged from those of the physician to the human body. In combating those terrible enemies the bacteria, which were pathogenic to animal life, the great difficulty was that many of the remedies effectual against the bacteria intefered with the vital functions of the patient. On the other hand, the physician could repeat remedies whenever the malignant symptons reappeared. Therefore antiseptics, more or less volatile, were sometimes more useful to the physician than others of a more permanent character, because they did not accumulate in the system of the patient. In preserving timber, the problem differed materially. The vital functions of the plant had ceased; stronger poisons, and substances which clogged up the cells and tissues, could be employed, provided always that they were of such a nature as not to injure the structure of the wood. But the remedy must be applied once for all. In the majority of cases where tim-

ber was once placed in engineering works the supply of the antiseptic could not be renewed. Therefore the very first condition was that the antiseptic should be of a permanent constitution. Let this rule be applied to the evidence offered during the discussion. Antiseptics for timber had been described: 1st, as coagulators of albumen; 2d, as germicides; 3d, as sterilizers, rendering the cells of the wood unfit for the development of fungi or bacteria; 4th, as germ-excluders, closing the entrances against the intrusions of the enemy.

Was not too much value still attached by some to the coagulation of the albumen in wood? Albumen formed an extremely small portion of the wood; in fir it varied from 0.5 to 0.9 per cent. Those parts of timber containing the smallest portions of albumen were nevertheless liable to decay; the mere coagulation of the albumen did not protect the bulk of the timber from destruction. Did coagulation preserve even the albumen itself from destruction? Sansom, Angus Smith,

and other authorities found that it did not. The author took a hard-boiled egg, a very complete specimen of coagulated albumen, removed the shell, and exposed it to the sea breezes on a high point of the Atlantic shore of the island of Mull. In a few days signs of putrefaction were visible; in eight days the albumen was coated with various species of micrococcus, cromogenes and other agents of destruction. The egg had become a mass of corruption. Coagulation had not protected albumen from putrefaction. What was the result when coagulation was produced, not by heat, but by the action of an antiseptic body? Did not the result depend mainly, if not altogether, upon the germicide properties of the antiseptic, and upon its abiding presence? Or, thus produced, did coagulation *per se* effect a new combination with permanent results? In the case of carbolic acid, a host of investigators said, No. Their experiments appeared to prove that carbolic acid was volatile in the air, soluble in the water, and that its compounds were not stable.

Boillat, in his experiments, realized the extreme conditions desired by those theorists who thought that carbolic acid had a permanent effect upon timber; he produced a perfect coagulation of albumen with an excess of carbolic acid. Yet a mere washing with water removed the whole of the carbolic acid, and the albumen putrefied on exposure to the air. Carbolic acid, therefore, would appear to have had no permanent effect upon albumen. The author agreed with Dr. Bernays that if coagulation by carbolic acid were desirable, 2 per cent. of that body might be retained; but having in view the foregoing evidence, what was the value of the coagulation theory at all as applied to timber-preserving? There had been some idea that carbolic acid lingered in the timber in some unrecognized form. The author had had occasion to test sleepers a few weeks after creosoting; if this were done before the carbolic acid had time to evaporate, it could be found in the wood by the ordinary tests, and a quantitative analysis made. On the other

hand, Dr. Tidy, who was not unwilling to find it in combination, had searched for it after twelve months, and had not found it by the ordinary tests, that is, in sufficient quantity to have any practical result. But whenever it was present there were tests subtle enough to detect it, even in such infinitesimal quantities as to have no practical value, as was evidenced by the experiments of Mr. Greville Williams. Notwithstanding theories and experiments, did carbolic acid, when put into timber, do any good there? Mr. Coisne, Mr. Greville Williams, and the author, not only never found it to have contributed to the success of old creosoted timber, but Mr. Coisne's experiments went further still. He injected woody fiber with light oils and an excess of tar acids, and the woods rotted, whilst the woods creosoted with heavy oils, and without any tar acids, were preserved.

There was one point respecting which there had been a consensus of opinion on the part of all who had taken part in the discussion, namely, that for the prepara-

tion of timber, creosoting had been undeniably more successful than corrosive sublimate, sulphate of copper, or chloride of zinc. Could this be at all due to carbolic acid? How was this possible, when a host of authorities proved that carbolic acid was less permanent in its effects than the three metallic salts alluded to, and very considerably less powerful as a germicide than corrosive sublimate or sulphate of copper. In a valuable work upon bacteria by Magnin and Sternberg there was a long list of antiseptics, with a statement as to their comparative potency as germicides, compiled from the latest authorities. Carbolic acid was low in the scale. Dr. Sternberg gave the strength of solutions of different kinds which had been found efficacious in preventing the development of the septic micrococcus, the following amongst many others :

Corrosive sublimate...	1	part in	40,000
Sulphate of copper....	1	"	400
Chloride of zinc.	1	"	200
Carbolic acid..........	1	"	200

These were in watery solution. To this must be added the statements that in oily solution the antiseptic power of carbolic acid was diminished, according to Sansom and Angus Smith; altogether it was nil according to Koch. It was evident that there was a vast accumulation of scientific evidence in confirmation of the continually reiterated statements of those practical men, who had had the largest and longest experience in preparing timber, to the effect that it was not to carbolic acid, but to other substances contained in the tar oils, that the superiority of the creosoting process over the other three methods was due. Mr. Lowe was well known as one of the highest scientific and practical authorities upon the tar acids, and he had given much valuable information in his communication to the Institution. On the other side, the absence of evidence was even more remarkable than many of those interested in this subject would perhaps have anticipated. No chemist had brought forward even a laboratory experiment in

proof of any permanent effect of carbolic acid upon albumen. No practical man had produced a proof that that substance had had any lasting effect upon timber. The author submitted that the claims of carbolic acid as an antiseptic for timber had not been proven.

What, then, were the substances in the creosote oils which had insured the superiority of that process over the others? If the author were asked the question, he would remark that the object being the prolonged preservation of timber, antiseptics should be chosen which remained longest in the timber. That the different constituents of the creosote oils, showed a gradation from the lightest and most volatile bodies at the carbolic, or left-hand end of the scale, up to the least volatile and most permanent bodies at the right-hand end. Divide the bulk of the oils roughly in half. Would the constituents of the right-hand half of themselves insure the preservation of the timber? Yes, excellently well. They contained germicides and solidifying mate-

rials; they were both sterilizers and germ-excluders; they would not evaporate, except at an enormously high temperature. Nevertheless in their united bulk they were perfectly fluid at a temperature of 100° Fahrenheit; they were insoluble in water; they could be injected into timber, in quantity exceeding the maximum which any engineer had as yet required. Would the other, or left-hand part of the group, taken by themselves, preserve timber? Much less perfectly, as they were more volatile. Would a still further fractioning to the left, if it were practicable, insure a better result? Not so, but a worse one still; for the lightest oils, which contained the greatest portion of the tar acids, were, like the tar acids themselves, the most volatile portions of all.

The author trusted that he had made clear his reasons for specially objecting to large percentages of tar acids. Take an honest heavy cresote, free from adulteration, free from mutilation, containing, say, 5 per cent. of tar acids. If this

sample were refused because it did not contain 8 or 10 per cent., the tar-distiller was induced to remove a large portion of the heavier constituents of the bodies to the right hand of the scale, in order to make the proportion of tar acids larger in the portion remaining. He believed that those heavier portions were the best. He thought that, provided the oils were sufficiently fluid at the temperature at which they were injected, there should be no restriction as to maximum specific gravity or maximum boiling-point. If larger and stronger doses of germicides were desired, it would be far better to put them into the wood in the shape of corrosive sublimate or sulphate of copper, in addition to the heavy oils. This could be done by a double process of preparation, with respect to which he had been lately experimenting.

Timber preserved by antiseptic treatment was an engineering material competing with other materials, both as to price and durability. Members of the Institution would appreciate the endeav-

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